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IDENTIFIERS	DACUM Process

ABSTRACT

This package consists of course syllabi, an instructor's handbook, and student laboratory manual for a 1-year vocational training program to prepare students for entry-level positions as advanced computer numerical control (CNC) and computer-assisted manufacturing (CAM) technicians.. The program was developed through a modification of the DACUM (Developing a Curriculum) technique. The course syllabi volume begins with the MASTER (Machine Tool Advanced Skills Technology Educational Resources) Program Consortium competency profile with 9 duties (and supporting technical workplace competencies): practice safety; apply mathematical concepts; interpret engineering drawings and control documents; recognize different manufacturing materials and processes; measure/inspect; perform conventional machining; perform advanced machining; use verification and communication systems; and program using CAM [computer-aided manufacturing] systems. The first volume contains the justification, documentation, and course syllabi for the courses. Each syllabus contains the following: course description; prerequisites; course objectives; required course materials; methods of instruction; lecture outline; lab outline; Secretary's Commission on Achieving Necessary Skills competencies taught; and appropriate reference materials. The instructor's handbook consists of technical training modules that include some or all of the following: time required; duty; task; objective(s); instructional materials list; references; student preparation; introduction; presentation outline; practical application; evaluation; summary; and attachments, including handouts, laboratory worksheets, and self-assessment with answer key. The handbook is arranged by duty grouping,

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with technical modules developed for each task box on the competency profile. The student laboratory manual contains a DACUM chart and learning modules. Each module in the student manual includes some or all of the following: objectives, outline, laboratory exercises, laboratory aids, and handouts. (MN)

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ED 422 486

Advanced CNC and CAM Series
Educational Resources for the Machine Tool Industry
Course Syllabi
Instructor's Handbook
Student Laboratory Manual

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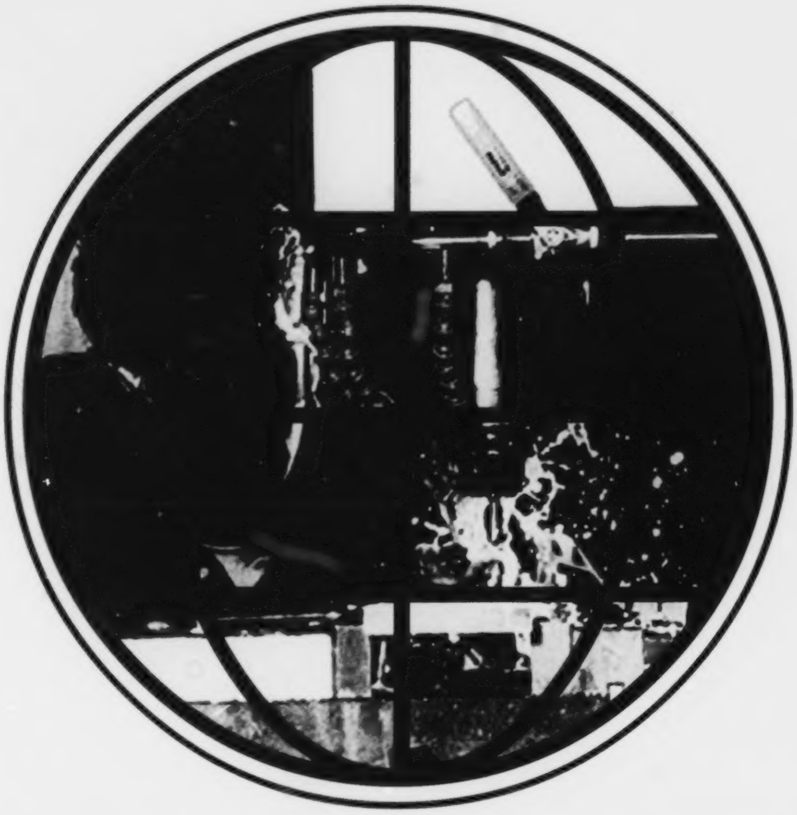
MACHINE TOOL ADVANCED SKILLS TECHNOLOGY EDUCATIONAL RESOURCES

MASTER

a consortium of educators and industry

EDUCATIONAL RESOURCES
FOR THE
MACHINE TOOL INDUSTRY



Advanced CNC and CAM Series
COURSE SYLLABI

Supported by the National Science Foundation's Advanced Technological Education Program

MACHINE TOOL ADVANCED SKILLS TECHNOLOGY EDUCATIONAL RESOURCES

MASTER

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EDUCATIONAL RESOURCES
FOR THE
MACHINE TOOL INDUSTRY

Advanced CNC and CAM Series

COURSE SYLLABI

Supported by the National Science Foundation's Advanced Technological Education Program

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National Science Foundation
Advanced Technological
Education Program

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National Science Foundation - Division of Undergraduate Education
MASTER Consortia of Employers and Educators

MASTER has built upon the foundation which was laid by the Machine Tool Advanced Skills Technology (MAST) Program. The MAST Program was supported by the U.S. Department of Education - Office of Vocational and Adult Education. Without this prior support MASTER could not have reached the level of quality and quantity that is contained in these project deliverables.

MASTER DEVELOPMENT CENTERS

Augusta Technical Institute - Central Florida Community College - Itawamba Community College - Moraine Valley Community College - San Diego City College (CACT) - Springfield Technical Community College - Texas State Technical College

INDUSTRIES

AB Lasers - AIRCAP/MTD - ALCOA - American Saw - AMOCO Performance Products - Automatic Switch Company - Bell Helicopter - Bowen Tool - Brunner - Chrysler Corp. - Chrysler Technologies - Conveyor Plus - Darr Caterpillar - Davis Technologies - Delta International - Devon - D. J. Plastics - Eaton Leonard - EBTEC - Electro-Motive - Emergency One - Eureka - Foster Mold - GeoDiamond/Smith International - Greenfield Industries - Hunter Douglas - Industrial Laser - ITT Engineered Valve - Kaiser Aluminum - Krueger International. - Laser Fare - Laser Services - Lockheed Martin - McDonnell Douglas - Mercury Tool - NASSCO - NutraSweet - Rapistan DEMAG - Reed Tool - ROHR, International - Searle - Solar Turbine - Southwest Fabricators - Smith & Wesson - Standard Refrigeration - Super Sagless - Taylor Guitars - Tecumseh - Teledyne Ryan - Thermal Ceramics - Thomas Lighting - FMC, United Defense - United Technologies Hamilton Standard

COLLEGE AFFILIATES

Aiken Technical College - Bevil Center for Advanced Manufacturing Technology - Chicago Manufacturing Technology Extension Center - Great Lakes Manufacturing Technology Center - Indiana Vocational Technical College - Milwaukee Area Technical College - Okaloosa-Walton Community College - Piedmont Technical College - Pueblo Community College - Salt Lake Community College - Spokane Community College - Texas State Technical Colleges at Harlington, Marshall, Sweetwater

FEDERAL LABS

Jet Propulsion Lab - Lawrence Livermore National Laboratory - L.B.J. Space Center (NASA) - Los Alamos Laboratory - Oak Ridge National Laboratory - Sandia National Laboratory - Several National Institute of Standards and Technology Centers (NIST) - Tank Automotive Research and Development Center (TARDEC) - Wright Laboratories

SECONDARY SCHOOLS

Aiken Career Center - Chicopee Comprehensive High School - Community High School (Moraine, IL) - Connally ISD - Consolidated High School - Evans High - Greenwood Vocational School - Hoover Sr. High - Killeen ISD - LaVega ISD - Lincoln Sr. High - Marlin ISD - Midway ISD - Moraine Area Career Center - Morse Sr. High - Point Lamar Sr. High -

Pontotoc Ridge Area Vocational Center - Putnam Vocational High School - San Diego Sr. High - Tupelo-Lee Vocational Center - Waco ISD - Westfield Vocational High School

ASSOCIATIONS

American Vocational Association (AVA) - Center for Occupational Research and Development (CORD) - CIM in Higher Education (CIMHE) - Heart of Texas Tech-Prep - Midwest (Michigan) Manufacturing Technology Center (MMTC) - National Coalition For Advanced Manufacturing (NACFAM) - National Coalition of Advanced Technology Centers (NCATC) - National Skills Standards Pilot Programs - National Tooling and Machining Association (NTMA) - New York Manufacturing Extension Partnership (NYMEP) - Precision Metalforming Association (PMA) - Society of Manufacturing Engineers (SME) - Southeast Manufacturing Technology Center (SMTC)

MASTER PROJECT EVALUATORS

Dr. James Hales, East Tennessee State University and William Ruxton, formerly with the National Tooling and Machine Association (NTMA)

NATIONAL ADVISORY COUNCIL MEMBERS

The National Advisory Council has provided input and guidance into the project since the beginning. Without their contributions, MASTER could not have been nearly as successful as it has been. Much appreciation and thanks go to each of the members of this committee from the project team.

Dr. Hugh Rogers-Dean of Technology-Central Florida Community College
Dr. Don Clark-Professor Emeritus-Texas A&M University
Dr. Don Edwards-Department of Management-Baylor University
Dr. Jon Botsford-Vice President for Technology-Pueblo Community College
Mr. Robert Swanson-Administrator of Human Resources-Bell Helicopter, TEXTRON
Mr. Jack Peck-Vice President of Manufacturing-Mercury Tool & Die
Mr. Don Hancock-Superintendent-Connally ISD

SPECIAL RECOGNITION

Dr. Hugh Rogers recognized the need for this project, developed the baseline concepts and methodology, and pulled together industrial and academic partners from across the nation into a solid consortium. Special thanks and singular congratulations go to Dr. Rogers for his extraordinary efforts in this endeavor.

Dr. Don Pierson served as the Principal Investigator for the first two years of MASTER. His input and guidance of the project during the formative years was of tremendous value to the project team. Special thanks and best wishes go to Dr. Pierson during his retirement and all his worldly travels.

All findings and deliverables resulting from MASTER are primarily based upon information provided by the above companies, schools and labs. We sincerely thank key personnel within these organizations for their commitment and dedication to this project. Including the national survey, more than 2,800 other companies and organizations participated in this project. We commend their efforts in our combined attempt to reach some common ground in precision manufacturing skills standards and curriculum development.

MASTER DEVELOPMENT CENTER, SAN DIEGO, CA
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Manufacturing in the San Diego Region

Manufacturing represents a major sector of the San Diego economy, accounting for almost one out of every four dollars (24%) of San Diego's gross regional product. The county is currently home to approximately 3,500 manufacturers employing roughly 110,000 San Diegans. During the first half of the 1990s, manufacturing in San Diego was hard hit by the downturn in military and defense spending which accompanied the end of the cold war. Many of the region's largest aerospace contractors rapidly downsized or moved their plants out of state, leaving a large supplier base that needed to modernize its manufacturing processes and convert to commercial markets. Rapid recovery of manufacturing in the region has been driven by San Diego's high tech research and development sectors in electronics, telecommunications, software, advanced materials, biotechnology, and medical instrumentation.

San Diego City College and its Center for Applied Competitive Technologies (CACT)

San Diego City College is an urban, minority institution, serving a large population of students from immigrant, disadvantaged, and low income households. In 1990, the College saw an opportunity to modernize its technical programs and improve the employment outlook for many of its students by agreeing to host one of the State of California's eight new regional manufacturing extension centers, the Centers for Applied Competitive Technologies (CACTs). The advanced technology centers were designed to assist local companies to modernize their manufacturing processes and convert from defense to newly emerging, technology-based commercial markets. This strategic partnership between the College and its resident CACT has proven to be highly successful. In developing the programs and lab facilities to serve the needs of regional manufacturing companies, the San Diego CACT and City College have simultaneously modernized the manufacturing and machine technology credit offerings of the College, thereby providing a well-trained, technically competent workforce for industry and enhancing career opportunities for students.

Development Team

- **Project Director:** Joan A. Stepsis, Ph.D., Dean/Director of the CACT-SD, served as programmatic manager and academic coordinator for the MASTER project.
- **Subject Matter Expert:** John C. Bollinger, Assoc. Prof. of Machine Technology, had programmatic responsibility for developing skill standards and course/program materials for the Advanced CNC and CAM component of the MASTER project. Professor Bollinger also served as the lead instructor for the MASTER instructional pilot for his specialty area.
- **Subject Matter Expert:** Douglas R. Welch, Assoc. Prof. of Manufacturing, had programmatic responsibility for developing skill standards and course/program materials for the Automated Equipment Technology (AET) and Machine Tool Integration (CIM) component of the MASTER project. Professor Welch also served as lead instructor for the MASTER instructional pilot for his specialty area.

MASTER Curriculum
Advanced CNC and CAM
(Certificate of Achievement)

		LEC	LAB	CR
CNC 140	Basic Principles of Machine Technology	3	3	4
CNC 150	Introduction to CNC and EDM	3	3	4
CNC 151	Introduction to CNC Verification and Communication	3	3	4
CNC 160	Introduction to CAD/CAM	3	3	4
CNC 161	Applications of CAD/CAM I	0	6	2
CNC 170	Introduction to CNC Controlled Vertical Machining and Electronic Discharge Machining (EDM)	3	3	4
CNC 171	Application of CNC Controlled Vertical Machining and Electronic Discharge Machining (EDM) I	0	6	2
CNC 180	Advanced CAD/CAM	3	3	4
CNC 181	Applications in Advanced CAD/CAM I	0	6	2
CNC 190	Introduction to CNC Controlled Turning	3	3	4
CNC 191	Applications of CNC Controlled Turning I	0	6	2

Introduction

MASTER research indicates that a minimum of one year of occupational study and training will prepare students possessing basic machining skills (safety, blueprint reading, math, measurement, etc.) with the additional skills necessary for the Advanced CNC and CAM trade. These findings led us to structure our pilot program to a one-year schedule.

In this one-year program, the students progress through a series of machine tool operations courses designed to constantly challenge their process skills on manual and Computer Numerical Controlled (CNC) machines. Along with comprehensive hands-on training, students also learn about the various types of materials and processes used by today's manufacturing industries. The Advanced CNC and CAM program at San Diego City College has been training entry-level technicians for many years and works closely with advisory committee members to ensure that the skills being taught are the skills needed in industry. Students who graduate from this course of study receive certificates of completion from San Diego City College. The Advanced CNC and CAM faculty worked closely with the **MASTER** staff and made every effort to adopt the recommended **MASTER** materials not only for the pilot program, but also for their non-**MASTER** students. The Advanced CNC and CAM program at San Diego City College is recognized throughout California by large and small manufacturing companies as a premier source for quality, entry-level technicians. Upon graduation, students are able to interpret complex drawings, select the correct materials, and perform all necessary machining processes. The curriculum has been designed to prepare students to enter the Advanced CNC and CAM trade. Laboratory work is emphasized with actual industrial equipment in order to prepare students for interesting, rewarding work in a wide variety of industries.

After many interviews with practitioners from industry and discussions with educators, managers, supervisors, and others involved with machine-related occupations (specifically Advanced CNC and CAM), the **MASTER** Consortium Partners have agreed to present our definition of an Advanced CNC and CAM technician as follows:

CNC MACHINIST - that person who programs, edits, sets up, and operates CNC lathes, mills and grinders to perform machining operations necessary to produce workpieces to referenced engineering standards.

This volume contains the justification, documentation, and course syllabi for the courses which we recommend as minimum training for individuals desiring to become an Advanced CNC and CAM technician.

The first and most important task of the **MASTER** program was the development of a foundation upon which all other works could be built. The **MASTER** Competency Profile is this foundation.

The MASTER Competency Profile

Development of Competency Profiles at each of the **MASTER** sites began with visits to representative companies for the purpose of surveying expert workers within the industry and occupational areas under investigation. Each site began the survey process by asking a subject matter expert in the targeted technical area, generally a member of its faculty, to employ a modified version of the generally accepted DACUM (Developing A Curriculum) method to categorize the major skills needed to work in the selected occupation. As source materials, the college instructors drew on their professional knowledge and experience of current industry requirements and trends. The initial skill standards developed by the subject matter experts underwent numerous internal reviews and revisions within each site, assuming final form as a series of structured survey and interview questions designed to elicit a simple yes or no response.

To determine an appropriate survey sample, each site compiled a database of its region's small and medium-sized manufacturers and searched for companies likely to employ workers in the targeted occupational area. The resulting cross-industry samples were sorted further to achieve a balance of technological capability and workforce size; the sample companies within each region were then asked to participate in the project. Willing respondents were scheduled for interviews.

During the company interviews, the **MASTER** staff asked expert workers to identify the primary duties and tasks performed by a typical worker and to consider the special skills and knowledge, traits and attitudes, and industry trends that would have an impact on worker training, employability, and performance both now and in the future. The interview results were analyzed to create individual profiles identifying the most common duties and skills required of workers at each company. These individual company Competency Profiles served two purposes. First, they showed, in a format that could be easily understood by both industries and educators, a picture of the occupational specialty at a given company at that particular time. Second, these individual company Competency Profiles furnished the company with a document over which they could claim ownership. This, in effect, made them real partners in the work of **MASTER**.

Data for all companies were then aggregated to develop a composite Competency Profile of industry skill standards within the selected occupational specialty area of Advanced CNC and CAM, as shown on the following page.

These same duties and tasks were then included in both the Texas and National Surveys for further validation. As a result of the surveys, additional refinements were made in the Competency Profiles. These changes were incorporated into the individual course syllabi which were used for the pilot program.

The **MASTER** Competency Profile for Advanced CNC and CAM has been included on the following page.

CNC Machinist
Competency Profile

Job Analysis conducted and prepared by

MASTER

***M**achine Tool **A**dvanced **S**kills*
***T**echnology **E**ducational*
***R**esources Program*
Consortium

CNC Machinist

Technical Workplace Competencies

Duties	Tasks			
A **Practice Safety**	A-1 Follow safety manuals and all safety regulations/ requirements	A-2 Use protective equipment	A-3 Follow safe operating procedures for hand and machine tools -	A-4 Maintain a clean and safe work environment
	A-5 MSDS/Control chemical hazards			
B **Apply Mathematical Concepts**	B-1 Perform basic arithmetic functions	B-2 Convert fractions/ decimals	B-3 Convert Metric/ English measurements	B-4 Perform basic algebraic operations
	B-5 Use practical geometry	B-6 Understand basic trigonometry	B-7 Calculate speeds and feeds for machining	B-8 Use coordinate systems
C **Interpret Engineering Drawings and Control Documents**	C-1 Identify basic layout of drawings	C-2 Identify basic types of drawings	C-3 Review blueprint notes and dimensions	C-4 List the purpose of each type of drawing
	C-5 Verify drawing elements	C-6 Practice geometric dimensioning and tolerancing (GD&T)	C-7 Analyze bill of materials (BOM)	C-8 Describe the relationship of engineering drawings to planning
	C-9 Understand and use quality systems	C-10 Verify standard requirements		
D **Recognize Different Manufacturing Materials and Processes**	D-1 Identify materials with desired properties	D-2 Identify materials and processes to produce a part	D-3 Describe the heat treating process	D-4 Test metal samples for hardness
	D-5 Understand welding operations			

CNC Machinist

Technical Workplace Competencies

Duties	Tasks			
E **Measure/Inspect**	E-1 Understand metrology terms	E-2 Select measurement tools	E-3 Measure with hand held instruments	E-4 Eliminate measurement variables
	E-5 Measure/inspect using surface plate and accessories	E-6 Inspect using stationary equipment		
F **Perform Conventional Machining**	F-1 Prepare and plan for machining operations	F-2 Use hand tools	F-3 Operate power saws	F-4 Operate drill presses
	F-5 Operate vertical milling machines	F-6 Operate horizontal milling machines	F-7 Operate metal cutting lathes	F-8 Operate grinding/ abrasive machines
G **Perform Advanced Machining**	G-1 Understand CNC basics	G-2 Program CNC machines	G-3 Operate CNC machining centers (mills)	G-4 Operate CNC turning centers (lathes)
H **Use Verification and Communication Systems**	H-1 Use personal computer	H-2 Use various operating systems	H-3 Use computer communications systems	H-4 Use verification systems
	H-5 Use the Internet			
I **Program Using CAM System**	I-1 Understand CAD/CAM programs	I-2 Manipulate CAD functions	I-3 Process simple toolpath data	I-4 Create advanced surface models
	I-5 Process complex toolpath functions			

CNC Machinist

Skills, Traits and Trends

Skills and Knowledge

Communication Skills
Use Measurement Tools
Use Inspection Devices
Mathematical Skills
Reading/Writing Skills
Knowledge of Safety Regulations
Practice Safety in the Workplace
Organizational Skills
Knowledge of Company Policies/Procedures
Mechanical Aptitude
Ability to Comprehend Written/Verbal Instructions
Basic Knowledge of Fasteners
Ability to Work as Part of a Team
Converse in the Technical Language of the Trade
Knowledge of Occupational Opportunities
Knowledge of Employee/Employer Responsibilities
Knowledge of Company Quality Assurance Activities
Practice Quality-Consciousness in Performance of the Job

Traits and Attitudes

Strong Work Ethic
Interpersonal Skills
Punctuality
Dependability
Honesty
Neatness
Safety Consciousness
Motivation
Responsible
Physical Ability
Professional
Trustworthy
Customer Relations
Personal Ethics

Tool/Equipment Proficiency

Machinist's Tools (e.g., calipers, dial indicators, magnetic tool holders, etc.)
Measuring Tools
Power Tools
Metal Lathe with Attachments
Drill Presses
Vertical Mill with Attachments
Power Saws
Power Drills
Hydraulic/Arbor Press
Heat Treatment Equipment
Hardness Testing Equipment
Grinding Machines with Attachments
Welding Equipment (SMAW, GMAW, FCAW, Plasma)
CNC Machining Center and Turning Center
Gear Producing Machines with Attachments
Jig Boring Machines
Alignment/Calibration Tools
Coolant Recovery Equipment
Computer
Ventilation Equipment
Forklift
Personal Safety Equipment
Oxyacetylene Equipment
Tool Storage Equipment
Workbenches
Vises
Pedestal Grinders
Weld Test Equipment
Optical Comparator
Coordinate Measurement Machine
Hydraulic/Pneumatic Training Equipment
Electrical Training Equipment
Safety Training Equipment

Current Trends

Statistical Process Control
Composites
Laser Machining
Advanced Computer Applications
Robotics
Environmental Concerns
Fiber Optic Controls
Automated Material Handling Equipment
Computer Integrated Manufacturing

The MASTER Pilot Program
Curriculum and Course Descriptions

After completing the Competency Profile for each occupational specialty area, each **MASTER** partner reviewed its existing curriculum against the industry-verified skill standards in order to identify a suitable foundation for new pilot training programs. Because each college had to comply with the requirements of its respective college system and appropriate state agency, the resulting pilot curricula for occupational specialty areas tended to vary in format and academic requirements (e.g., some programs were based on the semester system, others on the quarter system). Despite differences in the curricula developed at the partner colleges, each of the pilot programs was designed to achieve the following two goals mandated in the **MASTER** grant proposal:

> ***Pilot Program***: "Conduct a one year pilot program with 25 or more selected applicants at each college or advanced technology center to evaluate laboratory content and effectiveness, as measured by demonstrated competencies and indicators of each program area."
>
> ***Student Assessment***: "Identify global skills competencies of program applicants both at point of entrance and point of exit for entry-level and already-employed technicians."
>
> (*Note*: Not all occupational specialty areas were pilot-tested at all Development Centers; however, all partner colleges conducted one or more pilot programs.)

Included on the following page is the curriculum listing for the pilot program which was used to validate course syllabi for this occupational specialty area. The curriculum also shows the number of hours assigned to each of the courses (lecture, laboratory and credit hours). Also included is a description of each of the courses.

MASTER Curriculum
Advanced CNC and CAM
(Certificate of Achievement)

		LEC	LAB	CR
CNC 140	Basic Principles of Machine Technology	3	3	4
CNC 150	Introduction to CNC and EDM	3	3	4
CNC 151	Introduction to CNC Verification and Communication	3	3	4
CNC 160	Introduction to CAD/CAM	3	3	4
CNC 161	Applications of CAD/CAM I	0	6	2
CNC 170	Introduction to CNC Controlled Vertical Machining and Electronic Discharge Machining (EDM)	3	3	4
CNC 171	Application of CNC Controlled Vertical Machining and Electronic Discharge Machining (EDM) I	0	6	2
CNC 180	Advanced CAD/CAM	3	3	4
CNC 181	Applications in Advanced CAD/CAM I	0	6	2
CNC 190	Introduction to CNC Controlled Turning	3	3	4
CNC 191	Applications of CNC Controlled Turning I	0	6	2

MASTER Course Descriptions
Advanced CNC and CAM
(Certificate of Achievement)

CNC 140	**Basic Principles of Machine Technology** (3-3-4) This course offers the basic principles required in the Machine Technology field in regard to measurements, common formulas, machining applications, safety, and interpretation of basic drawings.
CNC 150	**Introduction to CNC and EDM** (3-3-4) The theory of advanced machining techniques, including numerically controlled mills and lathes and Electro-Discharge machining. Emphasis on introduction to CNC programming using "G" and "M" codes. Students in this class are expected to have previous machine laboratory experience or concurrent enrollment.
CNC 151	**Introduction to CNC Verification and Communication** (3-3-4) Theory and application of verification and communication of CNC programs.
CNC 160	**Introduction to CAD/CAM** (3-3-4) Introduction to CAD/CAM theories and software. The emphasis will be on the generation of CNC programs, at a basic level, for CNC mill and CNC lathe.
CNC 161	**Applications of CAD/CAM I** (0-6-2) Exercises in CAD/CAM to increase students efficiency and quality of work on the generation of CNC programs, at an intermediate level, for CNC mill and CNC lathe.
CNC 170	**Introduction to CNC Controlled Vertical Machining and Electronic Discharge Machining (EDM)** (3-3-4) Theory of CNC vertical machining techniques. Emphasis placed on basic operations of vertical machining center and EDM. Students in this class are expected to have previous machining experience.
CNC 171	**Application of CNC Controlled Vertical Machining and Electronic Discharge Machining (EDM) I** (0-6-2) Exercises in CNC vertical machining techniques and EDM at an intermediate level. This class is to allow students the opportunity to gain speed and efficiency in a hands-on environment. Students in this class are expected to have previous machining experience.
CNC 180	**Advanced CAD/CAM** (3-3-4) Advanced CAD/CAM theory and software. The emphasis will be on the generation of CNC programs, using advanced modeling techniques for both CNC mill and CNC lathe.

CNC 181 **Applications in Advanced CAD/CAM I** (0-6-2) Exercises in CAD/CAM theory and software at an intermediate level. The emphasis will be on the generation of CNC programs, at intermediate level, for both CNC mill and CNC lathe. This class is designed to allow the student the opportunity to improve efficiency in the application of immediate CAD/CAM.

CNC 190 **Introduction to CNC Controlled Turning** (3-3-4) Theory of CNC turning techniques. Emphasis placed on basic operations of CNC turning. Students in this class are expected to have previous machining experience..

CNC 191 **Applications of CNC Controlled Turning I** (0-6-2) Exercises in CNC turning techniques at an intermediate level. Emphasis placed on basic operations of CNC turning. The class is designed to allow the student the opportunity to gain speed and efficiency in the hands-on application of turning operations at an intermediate level. Students in this class are expected to have previous machining experience.

The MASTER
Technical Workplace Competencies
and
Course Crosswalk

After development of appropriate curricula for the pilot programs, each MASTER college began to develop individual course outlines for its assigned specialty area. The skill standards identified in the Competency Profile were cross walked against the technical competencies of the courses in the pilot curriculum. The resulting matrix provided a valuable tool for assessing whether current course content was sufficient or needed to be modified to ensure mastery of entry-level technical competencies. Exit proficiency levels for each of the technical competencies were further validated through industry wide surveys both in Texas and across the nation.

The Technical Workplace Competencies and Course Crosswalk on the following pages presents the match between industry—identified duties and tasks and the pilot curriculum for Advanced CNC and CAM. Course titles are shown in columns; duties and tasks, in rows. The Exit Proficiency Level Scale (see Figure 1), an ascending scale with 5 as the highest level of proficiency, includes marked boxes indicating whether the task is covered by the instructor during the course; the numbers 1–5 indicate the degree of attention given to the task and the corresponding proficiency expected on the part of the student upon completion of the course of studies. The crosswalk is intended to serve as an aide to other instructional designers and faculty in community college programs across the nation.

EXIT PROFICIENCY LEVEL SCALE					
Technical Workplace Competency	**1**	**2**	**3**	**4**	**5**
	Rarely	Routinely with Supervision	Routinely with Limited Supervision	Routinely Without Supervision	Initiates/ Improves/ Modifies and Supervises Others

Figure 1

Included on the following pages is the Technical Workplace Competencies and Course Crosswalk for the pilot program curriculum. This crosswalk validates the fact that the duties and tasks which were identified by industry as being necessary for entry-level employees have been incorporated into the development of the course syllabi.

Page 1

Advanced CNC and CAM

Technical Workplace Competencies
and
Course Crosswalk

	Basic Principles of Machine Technology	Intro. to CNC and EDM	Intro. to CNC Ver/Station/Communication	Intro. to CAD/CAM	Applications of CAD/CAM I	Intro. to CNC Controlled Vert. Mach./EDM	Applications-CNC Controlled Vert. Mach./EDM	Advanced CAD/CAM	Applications in Advanced CAD/CAM I	Intro to CNC Controlled Turning	Applications of CNC Controlled Turning I				EXIT PROFICIENCY LEVEL
A. PRACTICE SAFETY															
A-1 Follow Safety Manuals and All Safety Regulations/Requirements	I	R				R	R			R	M				4
A-2 Use Protective Equipment	I	R				R	R			R	M				4
A-3 Follow Safe Operating Procedures for Hand and Machine Tools	I	R				R	R			R	M				4
A-4 Maintain a Clean and Safe Work Environment	I	R				R	R			R	M				4
A-5 MSDS/Control Chemical Hazards	I	R				R	R			R	M				4
B. APPLY MATHEMATICAL CONCEPTS															
B-1 Perform Basic Arithmetic Functions	I	R	R	R	R	R	R	R	R	R	M				4
B-2 Convert Fractions/Decimals	I	R	R	R	R	R	R	R	R	R	M				4
B-3 Convert Metric/English Measurements	I	R	R	R	R	R	R	R	R	R	M				4
B-4 Perform Basic Algebraic Operations	I	R	R	R	R	R	R	R	R	R	M				4
B-5 Use Practical Geometry	I	R	R	R	R	R	R	R	R	R	M				4
B-6 Understand Basic Trigonometry	I	R	R	R	R	R	R	R	R	R	M				4
B-7 Calculate Speeds and Feeds for Machining	I	R	R	R	R	R	R	R	R	R	M				4
B-8 Use Coordinate Systems	I	R	R	R	R	R	R	R	R	R	M				4
C. INTERPRET ENGINEERING DRAWINGS AND CONTROL DOCUMENTS															
C-1 Identify Basic Layout of Drawings	I	R	R	R	R	R	R	R	R	R	M				4
C-2 Identify Basic Types of Drawings	I	R	R	R	R	R	R	R	R	R	M				4
C-3 Review Blueprint Notes and Dimensions	I	R	R	R	R	R	R	R	R	R	M				4
C-4 List the Purpose of Each Type of Drawing	I	R	R	R	R	R	R	R	R	R	M				4
C-5 Verify Drawing Elements	I	R	R	R	R	R	R	R	R	R	M				4
C-6 Practice Geometric Dimensioning and Tolerancing (GD&T)	I	R	R	R	R	R	R	R	R	R	M				4
C-7 Analyze Bill of Materials (BOM)	I	R	R	R	R	R	R	R	R	R	M				4
C-8 Describe the Relationship of Engineering Drawings to Planning	I	R	R	R	R	R	R	R	R	R	M				4
C-9 Understand and Use Quality Systems	I	R	R	R	R	R	R	R	R	R	M				4
C-10 Verify Standard Requirements	I	R	R	R	R	R	R	R	R	R	M				4
D. RECOGNIZE DIFFERENT MANUFACTURING MATERIALS AND PROCESSES ***															

*** These are addressed in the Machining Core Courses

I=Introduced and Taught R=Repeated and Reinforced M=Mastered

CNCXWALK1.PM6-010998

Page 2

Advanced CNC and CAM

Technical Workplace Competencies
and
Course Crosswalk

	Basic Principles of Machine Technology	Intro to CNC and EDM	Intro to CNC Verification/Communications	Intro to CAD/CAM	Applications of CAD/CAM I	Intro to CNC Controlled Vert Mills/EDM	Applications-CNC Controlled Vert Mills/EDM	Advanced CAD/CAM	Applications in Advanced CAD/CAM I	Intro to CNC Controlled Turning	Applications of CNC Controlled Turning I				EXIT PROFICI LEVE
E. MEASURE/INSPECT															
E-1 Understand Metrology Terms	I	R	R	R	R	R	R	R	R	R	M				4
E-2 Select Measurement Tools	I	R	R	R	R	R	R	R	R	R	M				4
E-3 Measure With Hand Instruments	I	R	R	R	R	R	R	R	R	R	M				4
E-4 Eliminate Measurement Variables	I	R	R	R	R	R	R	R	R	R	M				4
E-5 Measure/Inspect Using Surface Plate and Accessories	I	R	R	R	R	R	R	R	R	R	M				4
E-6 Inspect Using Stationary Equipment	I	R	R	R	R	R	R	R	R	R	M				4
F. PERFORM CONVENTIONAL MACHINING ***															
G. PERFORM ADVANCED MACHINING															
G-1 Understand CNC Basics		I				R	R			R	M				4
G-2 Program CNC Machines		I	R	R	R	R	R	R	R	R	M				5
G-3 Operate CNC Machining Centers (Mills)		I	R	R	R	R	R	R	R	R	M				5
G-4 Operate CNC Turning Centers (Lathes)		I	R	R	R	R	R	R	R	R	M				5
H. USE VERIFICATION AND COMMUNICATION SYSTEMS															
H-1 Use Personal Computer			I	R	R	R	R	R	R	R	M				5
H-2 Use Various Operating Systems			I	R	R	R	R	R	R	R	M				5
H-3 Use Computer Communications Systems			I	R	R	R	R	R	R	R	M				5
H-4 Use Verification Systems			I	R	R	R	R	R	R	R	M				5
H-5 Use the Internet			I	R	R	R	R	R	R	R	M				5
I. PROGRAM USING CAM SYSTEM															
I-1 Understand CAD/CAM Programs				I	R			R	M						5
I-2 Manipulate CAD Functions				I	R			R	M						5
I-3 Process Simple Toolpath Data				I	R			R	M						5
I-4 Create Advanced Surface Models				I	R			R	M						5
I-5 Process Complex Toolpath Functions				I	R			R	M						5

*** These are addressed in the Machining Core Courses

I=Introduced and Taught   R=Repeated and Reinforced   M=Mastered

SCANS

The Secretary's Commission on Achieving Necessary Skills (SCANS), U. S. Department of Labor, has identified in its "AMERICA 2000 REPORT" the following five competencies and a three-part foundation of skills and personal qualities that are needed for solid job performance:

COMPETENCIES:

Resources:	*Identifies, organizes, plans, and allocates resources*
Interpersonal:	*Works with others*
Information:	*Acquires and uses information*
Systems:	*Understands complex inter-relationships*
Technology:	*Works with a variety of technologies*

FOUNDATION SKILLS:

Basic Skills:	*Reads, writes, performs arithmetic and mathematical operations, listens, and speaks well*
Thinking Skills:	*Thinks creatively, makes decisions, solves problems, visualizes, knows how to learn, and reasons*
Personal Qualities:	*Displays responsibility, self-esteem, sociability, self-management, integrity, and honesty*

Recognizing the value of SCANS proficiencies to job performance as well as the growing mandate in many states to include SCANS activities in course curricula, **MASTER** asked survey respondents to review the SCANS skill sets in the context of the draft skill standards for each occupational specialty area. **MASTER** also incorporated an evaluation of SCANS competencies and foundation skills into its assessment of the pilot training curricula. The results were summarized in a crosswalk that allowed the **MASTER** staff to modify course contents where needed to strengthen the achievement of SCANS competencies.

As soft skills, the SCANS competencies are inherently difficult to quantify. **MASTER** realizes that some faculty will emphasize the SCANS more or less than others. In time, faculty will learn to make these types of SCANS activities an integral and important part of the teaching process.

MASTER Curriculum
Advanced CNC and CAM
(Certificate of Achievement)

		LEC	LAB	CR
CNC 140	Basic Principles of Machine Technology	3	3	4
CNC 150	Introduction to CNC and EDM	3	3	4
CNC 151	Introduction to CNC Verification and Communication	3	3	4
CNC 160	Introduction to CAD/CAM	3	3	4
CNC 161	Applications of CAD/CAM I	0	6	2
CNC 170	Introduction to CNC Controlled Vertical Machining and Electronic Discharge Machining (EDM)	3	3	4
CNC 171	Application of CNC Controlled Vertical Machining and Electronic Discharge Machining (EDM) I	0	6	2
CNC 180	Advanced CAD/CAM	3	3	4
CNC 181	Applications in Advanced CAD/CAM I	0	6	2
CNC 190	Introduction to CNC Controlled Turning	3	3	4
CNC 191	Applications of CNC Controlled Turning I	0	6	2

CNC 140

MASTER PROGRAM

Basic Principles of Machine Technology

COURSE SYLLABUS

Total lecture hours: 48 **Total lab hours: 48** **Credit hours: 4**

COURSE DESCRIPTION:

This course offers the basic principles required in the Machine Technology field relative to measurements, common formulas, machining applications, safety, and interpretation of basic drawings.

PREREQUISITES: NONE

COURSE OBJECTIVES

After successful completion of this course, the students will be able to:

1. Identify and demonstrate a thorough understand of common machine safety practices;
2. Identify common measuring instruments and their accessories;
3. Demonstrate proper use of common measuring instruments and their accessories;
4. Demonstrate proper care of common measuring instruments and their accessories;
5. Identify commonly used mathematical formulas used in the machining environment;
6. Demonstrate proper use of mathematical formulas used in the machining environment;
7. Use mathematical calculations and reference tables to determine typical numerical results needed in machining;
8. Identify common cutting tools and their accessories;
9. Demonstrate proper use and care of common cutting tools and their accessories;
10. Demonstrate reading and writing skills to read and prepare required documents for course work; and,
11. Demonstrate communication skills to interact successfully with members of working teams and instructor.

REQUIRED COURSE MATERIALS:

Textbooks: *Technology of Machine Tools,* Latest Edition; or

Blue Print Reading For Industry, Latest Edition; or
Machinery's Handbook, Industrial Press, Latest Edition

Lab Manual: None

Supplies:
Scientific Calculator
6 ruler

METHOD OF INSTRUCTION:

Lecture: Presentations will include: lecture with or without various audio–visual aids; discussion, debate, and/or critique; demonstrations; computer–assisted or other self–paced instruction; field trips or field assignments.

Laboratory: Laboratory will be a hands–on process.

Method of Evaluation: A student's grade will be based on multiple measures of performance. The assessment will measure development of independent critical thinking skills and will include evaluation of the student's ability to:

1. Perform the manipulative skills of the craft as required to satisfactorily complete laboratory assignments;
2. Apply theory to laboratory assignments;
3. Satisfactorily perform on written, oral, or practical examinations;
4. Satisfactorily perform on outside assignments including writing assignments/processing documents;
5. Contribute to class discussions;
6. Maintain attendance per current policy; and,
7. Follow all laboratory rules and safety regulations.

LECTURE OUTLINE

Lecture Topics	Contact Hrs.
Machine Shop Safety Practices	
A. Safety equipment	
B. Proper clothing for machining environment	
C. Proper attitudes for safety	
D. Chemicals in the workplace "MSDS"	
E. Fire hazards	
F. Proper personal hygiene	
G. Proper laboratory cleaning	
Measuring Instruments and Their Accessories	
A. Rulers	
B. Outside micrometers	

C. Vernier calipers
D. Dial calipers
E. Depth micrometers
F. Inside micrometers
G. Telescoping gauges
H. Edge finders
I. Test indicators
J. Dial indicators
K. Coordinate measuring machines

Mathematical Formulas

A. Calculator use
B. Fractions
C. Decimals
D. R.P.M. calculations
E. Feed calculations
F. Depth of cut calculations
G. Threading calculations
H. Tap drill calculations
I. Trigonometric applications to machine technology
J. Reference tables

Identification and Proper Care of Cutting Tools

A. End mills
B. Face mills
C. Center drills
D. Drills
E. Reamers
F. Single point boring head
G. Single point threading tools
H. Counter boring tools
I. Spot facing tools
J. Taps

Nomenclature and Functions of Machining Operations

A. Climb milling vs. conventional milling
B. Contouring: inside and outside
C. Pocketing
D. Center drilling
E. Drilling
F. Reaming
G. Single point boring
H. Single point threading: inside and outside
I. Counter boring
J. Spot facing
K. Tapping

Elements of Blue Print Reading as Applied to Machine Technology

A. Line types

B. Orthographic projections
C. Pictorial drawings
D. Detail drawings
E. Sectional drawings
G. Assembly drawings
H. Dimensions and tolerances
I. Drawing notes
J. Title blocks
K. Material listings
L. Surface finish callouts
M. Process documentation

Total Lecture Hours 48

LAB OUTLINE

Lab Topics	Contact Hrs.
Machine Shop Safety Practices	
Measuring Instruments and Their Accessories	
Mathematical Formulas	
Identification and Proper Care of Cutting Tools	
Functions of Machining Operations	
Elements of Blue Print Reading	
Total Lab Hours	48

COURSE OBJECTIVES: SCANS COMPETENCIES

The Secretary's Commission on Achieving Necessary Skills (SCANS), U.S. Department of Labor, has identified in its "AMERICA 2000 REPORT" that all students should develop a new set of competencies and foundation skills if they are to enjoy a productive, full and satisfying life. These are in addition to the Technical Workplace Competencies required by industry. SCANS is made up of five competencies and a three-part foundation of skills and personal qualities that are needed for solid job performance. All italicized headings in this section are direct quotations from "What Work Requires of Schools: A SCANS Report for America 2000."

The following activities will be performed by each student for successful completion of this course:

I. COMPETENCIES
  A. Resources: Identifies, organizes, plans, and allocates resources
    1. Allocates time to complete assigned tasks on schedule

        2. Determines and allocates required materials and resources for meeting objectives
        3. Evaluates skills, performance, and quality of work and provides feedback
    B. *Interpersonal: Works with others*
        1. Participates as a member of the team, contributing to group effort
        2. Provides individual assistance/direction to peers as requested
        3. Determines and meets expectations
        4. Exercises leadership qualities to effectively communicate ideas and make decisions.
        5. Negotiates resources in order to accomplish objectives
        6. Works well with all members of the class
    C. *Information: Acquires and uses information*
        1. Acquires and evaluates information
        2. Organizes and maintains information
        3. Interprets and communicates information
    D. *Systems: Understands complex inter-relationships*
        1. Understands and works well with social, organizational, and technological systems
        2. Monitors and corrects performance of system during operation
        3. Recommends modifications to system to improve performance
    E. *Technology: Works with a variety of technologies*
        1. Chooses relevant procedures, tools, and equipment
        2. Applies appropriate procedures and techniques to accomplish tasks
        3. Identifies or solves problems to maintain equipment

II. FOUNDATION SKILLS
    A. **Basic Skills:** Reads, writes, performs arithmetic and mathematical operations, listens and speaks
        1. ***Reading:*** *Locates, understands, and interprets written information in prose and in documents such as manuals, graphs, and schedules*
            a. Demonstrates basic reading skills including abilities to perceive main ideas, draw appropriate conclusions, detect a sequence, locate answers, find facts, and infer from written texts
            b. Demonstrates course specific reading skills including abilities to read, interpret, and comprehend information from text and supplemental materials on a level to facilitate productive independent and group study
            c. Demonstrates ability to read, interpret, and utilize information from course specific instruments (i.e., charts,

    diagrams, graphs, schematics, blueprints, flow charts, etc.)
    - d. Demonstrates ability to read, interpret, and follow schedules and procedural instructions in a timely and appropriate manner
    - e. Demonstrates ability to choose and use most appropriate reading method (skim, scan, or read for comprehension) for materials

2. *Writing: Communicates thoughts, ideas, information, and messages in writing; and creates documents such as letters, directions, manuals, reports, graphs, and flow charts*
    - a. Demonstrates basic writing skills including abilities to produce written documents which conform with accepted grammatical and communication standards required for effective daily functioning
    - b. Demonstrates effective written study skills including note taking, maintaining course specific journals, workbooks, manuals, etc.
    - c. Demonstrates technical writing skills in preparing outlines, summaries, time lines, flow charts, diagrams, etc. appropriate to materials covered
    - d. Demonstrates ability to complete all required writings in a timely, complete, and professional manner
    - e. Demonstrates competence in subject matter through the organization and presentation of answers to required written assessments

3. ***Arithmetic/Mathematics:** Perform basic computations and approaches practical problems by choosing appropriately from a variety of mathematical techniques*
    - a. Demonstrates proficiency in basic arithmetic functions including ability to add, subtract, multiply, and divide whole numbers, fractions, decimals, and percentages
    - b. Demonstrates ability to read, comprehend, and select appropriate math procedures to work basic math problems
    - c. Demonstrates ability to understand and perform multi-step computations
    - d. Demonstrates ability to read, interpret, and use standard measuring devices
    - e. Demonstrates ability to comprehend, retain, and utilize course specific measuring devices effectively
    - f. Demonstrates ability to understand, retain, and utilize higher mathematical formulas and functions required for course specific math performance

- g. Demonstrates ability to appropriately transfer mathematical calculations and information from paper to machines
- *4. Listening: Receives, attends to, interprets, and responds to verbal messages and other cues*
  - a. Functions at minimal or above required hearing levels to receive, attend, interpret, and respond to verbal messages and instructions and to safely operate machinery
  - b. Demonstrates ability to hear, comprehend, and appropriately follow directions
  - c. Demonstrates auditory ability to hear, comprehend, and utilize verbal classroom as well as other auditory instruction
  - d. Demonstrates ability to discriminate between essential and non-essential verbal information and react appropriately
  - e. Demonstrates ability to focus and fine-tune listening skills to receive, interpret, and respond to various sounds
  - f. Demonstrates ability and maturity to seek and receive additional individualized instruction as needed
- *5. Speaking: Organizes ideas and communicates orally*
  - a. Demonstrates appropriate listening and speaking skills in personal conversations
  - b. Demonstrates ability to choose and organize appropriate words to effectively communicate
  - c. Demonstrates ability to speak clearly and distinctly with appropriate volume, tone, and body language for situation
  - d. Demonstrates ability to spontaneously organize and present appropriate answers and/or short presentations for classroom and /or assessment purposes
  - e. Demonstrates ability to formulate, organize, and deliver major presentations to peers or groups
  - f. Demonstrates ability to speak effectively in one-on-one, small group, or large group presentations
  - g. Demonstrates ability to take responsibility for presentations

B. Thinking Skills: Thinks creatively, makes decisions, solves problems, visualizes, knows how to learn and reasons

- *1. Decision Making: Specifies goals and constraints, generates alternatives, considers risks, and evaluates and chooses best alternative*
  - a. Demonstrates ability to objectively assess personal strengths and weaknesses
  - b. Demonstrates ability to set realistic short-term and long-term goals

- c. Demonstrates ability to recognize and distinguish between positive and negative alternatives
- d. Demonstrates ability to identify potential pitfalls and take evasive actions
- e. Demonstrates ability to objectively and responsibly evaluate alternatives by testing hypotheses and selecting most appropriate response
- f. Demonstrates ability to profit from negative evaluations or mistakes by reformulating, redirecting, reconstructing, or retesting alternatives
- g. Demonstrates maturity in taking responsibility for decisions

2. ***Problem Solving:** Recognizes problems and devises and implements plan of action*
    - a. Demonstrates ability to detect problem through observation, inquiry, or directive
    - b. Demonstrates ability to grasp appropriate overview and degree of seriousness of problem and to behave responsibly in situation
    - c. Demonstrates ability to generate alternatives or options for problem solution
    - d. Demonstrates ability to research options, assess and evaluate options, and determine appropriate and best solution
    - e. Demonstrates ability to initiate and effect solution
    - f. Demonstrates ability to take responsibility for outcomes
    - g. Demonstrates ability to effectively problem solve in individual, team, or group situations
3. ***Seeing Things In the Mind's Eye:** Organizes, and processes symbols, pictures, graphs, objects, and other information*
    - a. Functions at minimum or above required visual levels in order to see, interpret, attend and respond to visual imagery and meet safety requirements for necessary machinery
    - b. Demonstrates ability to read, interpret, and act upon signs, symbols, and other visual cues
    - c. Demonstrates ability to visually discriminate in gross and fine imagery
    - d. Demonstrates ability to visualize abstractly
    - e. Demonstrates ability to apply visual imagery to applied tasks
4. ***Knowing How to Learn:** Use efficient learning techniques to acquire and apply new knowledge and skills*
    - a. Demonstrates mastery of basic reading, math, and language skills through application

- b. Demonstrates ability to translate abstract theory into practical application
- c. Demonstrates ability to incorporate and generalize new learning into a sequential learning process
- d. Demonstrates knowledge of good study skills and learning habits

5. ***Reasoning:*** *Discovers a rule or principle underlying the relationship between two or more objects and applies it when solving a problem*
   - a. Demonstrates use of simple logic
   - b. Demonstrates ability to distinguish relationships
   - c. Demonstrates ability to determine and isolate factors in relationships
   - d. Demonstrates and applies knowledge through practice
   - e. Recognizes that attitudes, skills, and practice are essential to productivity
   - f. Demonstrates ability to discriminate between positive and negative, and act accordingly

C. **Personal Qualities:** Displays responsibility, self-esteem, sociability, self-management, and integrity and honesty

1. ***Responsibility:*** *Exerts a high level of effort and perseveres towards goal attainment*
   - a. Demonstrates ability to formulate realistic and useful short and long term goals and complete steps necessary to timely achieve goals
   - b. Demonstrates ability to make adjustments, revisions, and changes to achieve goals in a cooperative and polite manner
   - c. Demonstrates ability to focus on task at hand and work to completion
   - d. Demonstrates good work ethics through regular attendance, adequate classroom preparations, and appropriate use of classroom time
   - e. Demonstrates maturity to take responsibility for actions
   - f. Demonstrates ability to cooperatively work in individual, team, and group situations in timely and effective manner
2. ***Self-Esteem:*** *Believes in own self-worth and maintains a positive view of self*
   - a. Presents a positive attitude toward tasks
   - b. Demonstrates ability to separate work and personal behaviors
   - c. Actively participates in learning opportunities by sharing knowledge and skills with peers and instructors

    d. Demonstrates ability to accept personal strengths and weaknesses and builds on positive behaviors
    e. Demonstrates ability to accept and use constructive criticism
    f. Accepts positive reinforcement in an appropriate manner

3. ***Sociability:*** *Demonstrates understanding, friendliness, adaptability, empathy, and politeness in group settings*
    a. Demonstrates appropriate and acceptable social behaviors in interactions
    b. Demonstrates ability to work cooperatively in individual, team, or group situations
    c. Demonstrates active interest in peers by offering assistance, sharing resources, and sharing knowledge in a professional and acceptable manner
    d. Demonstrates professional work ethic by separating work and personal social behaviors and acting accordingly
4. ***Self-Management:*** *Assesses self accurately, sets personal goals, monitors progress, and exhibits self-control*
    a. Accepts personal strengths and weaknesses and uses the same for positive advancement
    b. Demonstrates ability to continuously set, assess, choose, and modify objectives as the situation demands in an appropriate manner
    c. Demonstrates ability to formulate and follow personal schedules
    d. Demonstrates ability to wisely use classroom time
    e. Demonstrates use of good study habits and skills
    f. Demonstrates maturity to take responsibility for own actions
5. ***Integrity/Honesty:*** *Chooses ethical courses of action*
    a. Knows and demonstrates ability to distinguish between positive and negative behaviors
    b. Demonstrates honesty and integrity in working with peers and supervisors
    c. Takes full responsibility for personal actions
    d. Demonstrates understanding of consequences for negative ethical behaviors and accepts responsibility for same when applicable
    e. Demonstrates positive work and social ethics in undertakings

Appropriate Reference Materials:

1. MASTER Technical Modules:
    CNC-A1 through CNC-A5;

CNC-B1 through CNC-B8;
CNC-C1 through CNC-C10; and
CNC-E1 through CNC-E6.

CNC 140
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MASTER PROGRAM

Introduction to CNC and EDM

COURSE SYLLABUS

Total lecture hours: 48 **Total lab hours: 48** **Credit hours: 4**

COURSE DESCRIPTION:

Theory of advanced machining techniques including numerically controlled mills and lathes and Electro–Discharge machining. Emphasis on introduction to CNC programming using "G" and "M" codes. Students in this class are expected to have previous machine laboratory experience or concurrent enrollment.

PREREQUISITES: **Basic Principles for Machine Technology or concurrent enrollment**

COURSE OBJECTIVES:

After successful completion of this course, the students will be able to:

1. Identify CNC Mills and Lathes, their controls and accessories;
2. Identify EDM machines, their controls and accessories;
3. Use charts, reference tables, math calculations to determine speeds and feeds;
4. Demonstrate the programming of CNC machines;
5. Use EDM processes for machining components;
6. Demonstrate proper use of personal computers;
7. Demonstrate a basic understanding of the common DOS and windows commands as used on personal computers to create various programs;
8. Demonstrate reading and writing skills to read and prepare required documents for course work; and,
9. Demonstrate communication skills to interact successfully with members of working teams and instructor.

REQUIRED COURSE MATERIALS:

Textbooks: *Technology of Machine Tools,* Latest Edition, or
Fundamentals of Numerical Control, Latest Edition, or
Computer Numerical Control: From Programming to Networking, Latest Edition

Lab Manual: None

Supplies:

6" ruler
Scientific Calculator
Assorted small end mills
Computer Diskettes

METHOD OF INSTRUCTION:

Lecture:	Presentations will include lecture, with or without, various audio-visual aids; discussion, debate, and/or critique; demonstration; computer–assisted or other self-paced instruction; field trips or field assignments.
Laboratory:	Laboratory will be a hands–on process utilizing specifically planned instructional activities or "live" work..

Method of Evaluation: A student's grade will be based on multiple measures of performance. The assessment will measure development of independent critical thinking skills and will include evaluation of the student's ability to:

1. Perform the manipulative skills of the craft as required to satisfactorily complete laboratory assignments;
2. Apply theory to laboratory assignments;
3. Satisfactorily perform on written, oral, or practical examinations;
4. Satisfactorily perform on outside assignments including writing assignments;
5. Contribute to class discussions;
6. Maintain attendance per current policy; and,
7. Follow all laboratory rules and safety regulations.

LECTURE OUTLINE:

Lecture Topics	Contact Hrs.
CNC Machines	
A. Mills	
B. Lathes	
C. Machining Centers	
D. Grinders	
Electro–Discharge Machines	
A. Theory of Operation	
B. Rigid Electrode	
C. Wire Electrode	
Controls	
A. Mini–computers	
B. Personal computers	
C. Anilam Control	

D. Fadal Control
E. Fanuc Control
Personal Computers
A. Basic Terminology
B. Basic Operation
C. Basic DOS Commands
Programming
A. Mills
B. Lathes

Total Lecture Hours 48

LAB OUTLINE:

Lab Topics	**Contact Hrs.**
CNC Machines	
Electro–Discharge Machines	
Controls	
Personal Computers	
Programming	
Total Lab Hours	**48**

COURSE OBJECTIVES: SCANS COMPETENCIES

The Secretary's Commission on Achieving Necessary Skills (SCANS), U.S. Department of Labor, has identified in its "AMERICA 2000 REPORT" that all students should develop a new set of competencies and foundation skills if they are to enjoy a productive, full and satisfying life. These are in addition to the Technical Workplace Competencies required by industry. SCANS is made up of five competencies and a three-part foundation of skills and personal qualities that are needed for solid job performance. All italicized headings in this section are direct quotations from "What Work Requires of Schools: A SCANS Report for America 2000."

The following activities will be performed by each student for successful completion of this course:

I. COMPETENCIES

- *A. Resources: Identifies, organizes, plans, and allocates resources*
    1. **Allocates time to complete assigned tasks on schedule**
    2. **Determines and allocates required materials and resources for meeting objectives**
    3. **Evaluates skills, performance, and quality of work and provides feedback**

- *B. Interpersonal: Works with others*
  1. Participates as a member of the team, contributing to group effort
  2. Provides individual assistance/direction to peers as requested
  3. Determines and meets expectations
  4. Exercises leadership qualities to effectively communicate ideas and make decisions.
  5. Negotiates resources in order to accomplish objectives
  6. Works well with all members of the class
- *C. Information: Acquires and uses information*
  1. Acquires and evaluates information
  2. Organizes and maintains information
  3. Interprets and communicates information
- *D. Systems: Understands complex inter-relationships*
  1. Understands and works well with social, organizational, and technological systems
  2. Monitors and corrects performance of system during operation
  3. Recommends modifications to system to improve performance
- *E. Technology: Works with a variety of technologies*
  1. Chooses relevant procedures, tools, and equipment
  2. Applies appropriate procedures and techniques to accomplish tasks
  3. Identifies or solves problems to maintain equipment

II. FOUNDATION SKILLS

- A. **Basic Skills:** Reads, writes, performs arithmetic and mathematical operations, listens and speaks
  - *1. **Reading:** Locates, understands, and interprets written information in prose and in documents such as manuals, graphs, and schedules*
    - a. Demonstrates basic reading skills including abilities to perceive main ideas, draw appropriate conclusions, detect a sequence, locate answers, find facts, and infer from written texts
    - b. Demonstrates course specific reading skills including abilities to read, interpret, and comprehend information from text and supplemental materials on a level to facilitate productive independent and group study
    - c. Demonstrates ability to read, interpret, and utilize information from course specific instruments (i.e., charts, diagrams, graphs, schematics, blueprints, flow charts, etc.)

   d. Demonstrates ability to read, interpret, and follow schedules and procedural instructions in a timely and appropriate manner
   e. Demonstrates ability to choose and use most appropriate reading method (skim, scan, or read for comprehension) for materials

2. ***Writing:*** *Communicates thoughts, ideas, information, and messages in writing; and creates documents such as letters, directions, manuals, reports, graphs, and flow charts*
   a. Demonstrates basic writing skills including abilities to produce written documents which conform with accepted grammatical and communication standards required for effective daily functioning
   b. Demonstrates effective written study skills including note taking, maintaining course specific journals, workbooks, manuals, etc.
   c. Demonstrates technical writing skills in preparing outlines, summaries, time lines, flow charts, diagrams, etc. appropriate to materials covered
   d. Demonstrates ability to complete all required writings in a timely, complete, and professional manner
   e. Demonstrates competence in subject matter through the organization and presentation of answers to required written assessments

3. ***Arithmetic/Mathematics:*** *Perform basic computations and approaches practical problems by choosing appropriately from a variety of mathematical techniques*
   a. Demonstrates proficiency in basic arithmetic functions including ability to add, subtract, multiply, and divide whole numbers, fractions, decimals, and percentages
   b. Demonstrates ability to read, comprehend, and select appropriate math procedures to work basic math problems
   c. Demonstrates ability to understand and perform multi-step computations
   d. Demonstrates ability to read, interpret, and use standard measuring devices
   e. Demonstrates ability to comprehend, retain, and utilize course specific measuring devices effectively
   f. Demonstrates ability to understand, retain, and utilize higher mathematical formulas and functions required for course specific math performance

- g. Demonstrates ability to appropriately transfer mathematical calculations and information from paper to machines

4. ***Listening:** Receives, attends to, interprets, and responds to verbal messages and other cues*
    - a. Functions at minimal or above required hearing levels to receive, attend, interpret, and respond to verbal messages and instructions and to safely operate machinery
    - b. Demonstrates ability to hear, comprehend, and appropriately follow directions
    - c. Demonstrates auditory ability to hear, comprehend, and utilize verbal classroom as well as other auditory instruction
    - d. Demonstrates ability to discriminate between essential and non-essential verbal information and react appropriately
    - e. Demonstrates ability to focus and fine-tune listening skills to receive, interpret, and respond to various sounds
    - f. Demonstrates ability and maturity to seek and receive additional individualized instruction as needed
5. ***Speaking**: Organizes ideas and communicates orally*
    - a. Demonstrates appropriate listening and speaking skills in personal conversations
    - b. Demonstrates ability to choose and organize appropriate words to effectively communicate
    - c. Demonstrates ability to speak clearly and distinctly with appropriate volume, tone, and body language for situation
    - d. Demonstrates ability to spontaneously organize and present appropriate answers and/or short presentations for classroom and /or assessment purposes
    - e. Demonstrates ability to formulate, organize, and deliver major presentations to peers or groups
    - f. Demonstrates ability to speak effectively in one-on-one, small group, or large group presentations
    - g. Demonstrates ability to take responsibility for presentations

B. **Thinking Skills:** Thinks creatively, makes decisions, solves problems, visualizes, knows how to learn and reasons

1. ***Decision Making:** Specifies goals and constraints, generates alternatives, considers risks, and evaluates and chooses best alternative*
    - a. Demonstrates ability to objectively assess personal strengths and weaknesses

- b. Demonstrates ability to set realistic short-term and long-term goals
- c. Demonstrates ability to recognize and distinguish between positive and negative alternatives
- d. Demonstrates ability to identify potential pitfalls and take evasive actions
- e. Demonstrates ability to objectively and responsibly evaluate alternatives by testing hypotheses and selecting most appropriate response
- f. Demonstrates ability to profit from negative evaluations or mistakes by reformulating, redirecting, reconstructing, or retesting alternatives
- g. Demonstrates maturity in taking responsibility for decisions

2. *Problem Solving: Recognizes problems and devises and implements plan of action*
    - a. Demonstrates ability to detect problem through observation, inquiry, or directive
    - b. Demonstrates ability to grasp appropriate overview and degree of seriousness of problem and to behave responsibly in situation
    - c. Demonstrates ability to generate alternatives or options for problem solution
    - d. Demonstrates ability to research options, assess and evaluate options, and determine appropriate and best solution
    - e. Demonstrates ability to initiate and effect solution
    - f. Demonstrates ability to take responsibility for outcomes
    - g. Demonstrates ability to effectively problem solve in individual, team, or group situations
3. *Seeing Things In the Mind's Eye: Organizes, and processes symbols, pictures, graphs, objects, and other information*
    - a. Functions at minimum or above required visual levels in order to see, interpret, attend and respond to visual imagery and meet safety requirements for necessary machinery
    - b. Demonstrates ability to read, interpret, and act upon signs, symbols, and other visual cues
    - c. Demonstrates ability to visually discriminate in gross and fine imagery
    - d. Demonstrates ability to visualize abstractly
    - e. Demonstrates ability to apply visual imagery to applied tasks

4. ***Knowing How to Learn:** Use efficient learning techniques to acquire and apply new knowledge and skills*
    a. Demonstrates mastery of basic reading, math, and language skills through application
    b. Demonstrates ability to translate abstract theory into practical application
    c. Demonstrates ability to incorporate and generalize new learning into a sequential learning process
    d. Demonstrates knowledge of good study skills and learning habits
5. ***Reasoning:** Discovers a rule or principle underlying the relationship between two or more objects and applies it when solving a problem*
    a. Demonstrates use of simple logic
    b. Demonstrates ability to distinguish relationships
    c. Demonstrates ability to determine and isolate factors in relationships
    d. Demonstrates and applies knowledge through practice
    e. Recognizes that attitudes, skills, and practice are essential to productivity
    f. Demonstrates ability to discriminate between positive and negative, and act accordingly

C. **Personal Qualities:** Displays responsibility, self-esteem, sociability, self-management, and integrity and honesty

1. ***Responsibility:** Exerts a high level of effort and perseveres towards goal attainment*
    a. Demonstrates ability to formulate realistic and useful short and long term goals and complete steps necessary to timely achieve goals
    b. Demonstrates ability to make adjustments, revisions, and changes to achieve goals in a cooperative and polite manner
    c. Demonstrates ability to focus on task at hand and work to completion
    d. Demonstrates good work ethics through regular attendance, adequate classroom preparations, and appropriate use of classroom time
    e. Demonstrates maturity to take responsibility for actions
    f. Demonstrates ability to cooperatively work in individual, team, and group situations in timely and effective manner
2. ***Self-Esteem:** Believes in own self-worth and maintains a positive view of self*
    a. Presents a positive attitude toward tasks

- b. Demonstrates ability to separate work and personal behaviors
- c. Actively participates in learning opportunities by sharing knowledge and skills with peers and instructors
- d. Demonstrates ability to accept personal strengths and weaknesses and builds on positive behaviors
- e. Demonstrates ability to accept and use constructive criticism
- f. Accepts positive reinforcement in an appropriate manner

3. ***Sociability:** Demonstrates understanding, friendliness, adaptability, empathy, and politeness in group settings*
    - a. Demonstrates appropriate and acceptable social behaviors in interactions
    - b. Demonstrates ability to work cooperatively in individual, team, or group situations
    - c. Demonstrates active interest in peers by offering assistance, sharing resources, and sharing knowledge in a professional and acceptable manner
    - d. Demonstrates professional work ethic by separating work and personal social behaviors and acting accordingly
4. ***Self-Management:** Assesses self accurately, sets personal goals, monitors progress, and exhibits self-control*
    - a. Accepts personal strengths and weaknesses and uses the same for positive advancement
    - b. Demonstrates ability to continuously set, assess, choose, and modify objectives as the situation demands in an appropriate manner
    - c. Demonstrates ability to formulate and follow personal schedules
    - d. Demonstrates ability to wisely use classroom time
    - e. Demonstrates use of good study habits and skills
    - f. Demonstrates maturity to take responsibility for own actions
5. ***Integrity/Honesty:** Chooses ethical courses of action*
    - a. Knows and demonstrates ability to distinguish between positive and negative behaviors
    - b. Demonstrates honesty and integrity in working with peers and supervisors
    - c. Takes full responsibility for personal actions
    - d. Demonstrates understanding of consequences for negative ethical behaviors and accepts responsibility for same when applicable
    - e. Demonstrates positive work and social ethics in undertakings

Appropriate Reference Materials:

1. MASTER Technical Modules:
    - CNC-A1 through CNC-A6;
    - CNC-B1 through CNC-B8;
    - CNC-C1 through CNC-C10;
    - CNC-E1 through CNC-E6; and,
    - CNC-G1 through CNC-G4.
2. *Anilam Vertical Machining Program Manual,* Latest Edition
3. *Bendix Dynapath Manual,* Latest Edition
4. *Hansvedt Manual,* Latest Edition
5. *Fadal Programming Manual,* Latest Edition
6. *Bridgeport Programming Manual,* Latest Edition
7. *Fanuc6T Programming Manual,* Latest Edition
8. *Anilam Lathemate Program Manual,* Latest Edition

CNC 150
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MASTER PROGRAM

Introduction to CNC Verification and Communication

COURSE SYLLABUS

Total lecture hours: 48 **Total lab hours: 48** **Credit hours: 4**

COURSE DESCRIPTION:

Theory and application of verification and communication of CNC programs.

PREREQUISITES: **Introduction to CNC and EDM or concurrent enrollment**

COURSE OBJECTIVES:

After successful completion of this course, the students will be able to:
1. Identify various methods of verifying CNC programs;
2. Identify various methods of communicating with CNC machines;
3. Demonstrate proper use of personal computers;
4. Demonstrate a basic understanding of the common DOS and Windows commands as used on personal computers to create various programs;
5. Demonstrate reading and writing skills to read and prepare required documents for course work; and,
6. Demonstrate communication skills to interact successfully with members of working teams and instructor.

REQUIRED COURSE MATERIALS:

Textbooks: ***Technology of Machine Tools***, McGraw Hill, Latest Edition
Computer Numerical Control: From Programming to Networking, Reston Publishing Company, Latest Edition

Lab Manual: None

Supplies:
Computer Diskettes
Calculator

METHOD OF INSTRUCTION:

Lecture: Presentations will include lecture, with or without, various audio-visual aids; discussion, debate, and/or critique; demonstration; computer–assisted or other self–paced instruction; field trips or field assignments.

Laboratory: Laboratory will be a hands–on process utilizing specifically planned instructional activities or "live" work..

Method of Evaluation: A student's grade will be based on multiple measures of performance. The assessment will measure development of independent critical thinking skills and will include evaluation of the student's ability to:

1. Perform the manipulative skills of the craft as required to satisfactorily complete laboratory assignments;
2. Apply theory to laboratory assignments;
3. Satisfactorily perform on written, oral, or practical examinations/processing documents;
4. Satisfactorily perform on outside assignments including writing assignments;
5. Contribute to class discussions;
6. Maintain attendance per current policy; and,
7. Follow all laboratory rules and safety regulations.

LECTURE OUTLINE:

Lecture Topics	Contact Hrs.
CNC Verification	
A. Graphing	
B. Solid Modeling Verification Software	
C. Shaded Model Verification Software	
D. Back–Plotting	
E. Graphics on Controller	
CNC Communications	
A. Theory of Communication	
B. RS–232 Interface	
C. Tape Loading	
D. Downloading	
E. Uploading	
F. Handshaking	
G. Communication using CAM Software	
H. Greco System's Communication	
Controls	
A. Fadal Controller	
B. Personal Computers	

C. Anilam Control
D. Fanuc Control
E. Dynapath System 10

Personal Computers

A. Basic Terminology
B. Basic Operation
C. Basic DOS Commands

Total Lecture Hours	**48**

LAB OUTLINE:

Lab Topics	**Contact Hrs.**
CNC Verification	
CNC Communications	
Controls	
Personal Computers	
Total Lab Hours	48

COURSE OBJECTIVES: SCANS COMPETENCIES

The Secretary's Commission on Achieving Necessary Skills (SCANS), U.S. Department of Labor, has identified in its "AMERICA 2000 REPORT" that all students should develop a new set of competencies and foundation skills if they are to enjoy a productive, full and satisfying life. These are in addition to the Technical Workplace Competencies required by industry. SCANS is made up of five competencies and a three-part foundation of skills and personal qualities that are needed for solid job performance. All italicized headings in this section are direct quotations from "What Work Requires of Schools: A SCANS Report for America 2000."

The following activities will be performed by each student for successful completion of this course:

I. COMPETENCIES
  A. *Resources: Identifies, organizes, plans, and allocates resources*
    1. Allocates time to complete assigned tasks on schedule
    2. Determines and allocates required materials and resources for meeting objectives
    3. Evaluates skills, performance, and quality of work and provides feedback
  B. *Interpersonal: Works with others*
    1. Participates as a member of the team, contributing to group effort

2. Provides individual assistance/direction to peers as requested
3. Determines and meets expectations
4. Exercises leadership qualities to effectively communicate ideas and make decisions.
5. Negotiates resources in order to accomplish objectives
6. Works well with all members of the class

C. Information: Acquires and uses information
1. Acquires and evaluates information
2. Organizes and maintains information
3. Interprets and communicates information

D. Systems: Understands complex inter-relationships
1. Understands and works well with social, organizational, and technological systems
2. Monitors and corrects performance of system during operation
3. Recommends modifications to system to improve performance

E. Technology: Works with a variety of technologies
1. Chooses relevant procedures, tools, and equipment
2. Applies appropriate procedures and techniques to accomplish tasks
3. Identifies or solves problems to maintain equipment

II. FOUNDATION SKILLS

A. **Basic Skills:** Reads, writes, performs arithmetic and mathematical operations, listens and speaks

*1. **Reading:** Locates, understands, and interprets written information in prose and in documents such as manuals, graphs, and schedules*

- a. Demonstrates basic reading skills including abilities to perceive main ideas, draw appropriate conclusions, detect a sequence, locate answers, find facts, and infer from written texts
- b. Demonstrates course specific reading skills including abilities to read, interpret, and comprehend information from text and supplemental materials on a level to facilitate productive independent and group study
- c. Demonstrates ability to read, interpret, and utilize information from course specific instruments (i.e., charts, diagrams, graphs, schematics, blueprints, flow charts, etc.)
- d. Demonstrates ability to read, interpret, and follow schedules and procedural instructions in a timely and appropriate manner

   e. Demonstrates ability to choose and use most appropriate reading method (skim, scan, or read for comprehension) for materials

2. ***Writing:*** *Communicates thoughts, ideas, information, and messages in writing; and creates documents such as letters, directions, manuals, reports, graphs, and flow charts*
   a. Demonstrates basic writing skills including abilities to produce written documents which conform with accepted grammatical and communication standards required for effective daily functioning
   b. Demonstrates effective written study skills including note taking, maintaining course specific journals, workbooks, manuals, etc.
   c. Demonstrates technical writing skills in preparing outlines, summaries, time lines, flow charts, diagrams, etc. appropriate to materials covered
   d. Demonstrates ability to complete all required writings in a timely, complete, and professional manner
   e. Demonstrates competence in subject matter through the organization and presentation of answers to required written assessments

3. ***Arithmetic/Mathematics:*** *Perform basic computations and approaches practical problems by choosing appropriately from a variety of mathematical techniques*
   a. Demonstrates proficiency in basic arithmetic functions including ability to add, subtract, multiply, and divide whole numbers, fractions, decimals, and percentages
   b. Demonstrates ability to read, comprehend, and select appropriate math procedures to work basic math problems
   c. Demonstrates ability to understand and perform multi-step computations
   d. Demonstrates ability to read, interpret, and use standard measuring devices
   e. Demonstrates ability to comprehend, retain, and utilize course specific measuring devices effectively
   f. Demonstrates ability to understand, retain, and utilize higher mathematical formulas and functions required for course specific math performance
   g. Demonstrates ability to appropriately transfer mathematical calculations and information from paper to machines

4. ***Listening:*** *Receives, attends to, interprets, and responds to verbal messages and other cues*

- a. Functions at minimal or above required hearing levels to receive, attend, interpret, and respond to verbal messages and instructions and to safely operate machinery
- b. Demonstrates ability to hear, comprehend, and appropriately follow directions
- c. Demonstrates auditory ability to hear, comprehend, and utilize verbal classroom as well as other auditory instruction
- d. Demonstrates ability to discriminate between essential and non-essential verbal information and react appropriately
- e. Demonstrates ability to focus and fine-tune listening skills to receive, interpret, and respond to various sounds
- f. Demonstrates ability and maturity to seek and receive additional individualized instruction as needed

5. Speaking: Organizes ideas and communicates orally

- a. Demonstrates appropriate listening and speaking skills in personal conversations
- b. Demonstrates ability to choose and organize appropriate words to effectively communicate
- c. Demonstrates ability to speak clearly and distinctly with appropriate volume, tone, and body language for situation
- d. Demonstrates ability to spontaneously organize and present appropriate answers and/or short presentations for classroom and /or assessment purposes
- e. Demonstrates ability to formulate, organize, and deliver major presentations to peers or groups
- f. Demonstrates ability to speak effectively in one-on-one, small group, or large group presentations
- g. Demonstrates ability to take responsibility for presentations

B. Thinking Skills: Thinks creatively, makes decisions, solves problems, visualizes, knows how to learn and reasons

***1. Decision Making:** Specifies goals and constraints, generates alternatives, considers risks, and evaluates and chooses best alternative*

- a. Demonstrates ability to objectively assess personal strengths and weaknesses
- b. Demonstrates ability to set realistic short-term and long-term goals
- c. Demonstrates ability to recognize and distinguish between positive and negative alternatives
- d. Demonstrates ability to identify potential pitfalls and take evasive actions

    e. Demonstrates ability to objectively and responsibly evaluate alternatives by testing hypotheses and selecting most appropriate response
    f. Demonstrates ability to profit from negative evaluations or mistakes by reformulating, redirecting, reconstructing, or retesting alternatives
    g. Demonstrates maturity in taking responsibility for decisions

2. *Problem Solving: Recognizes problems and devises and implements plan of action*
    a. Demonstrates ability to detect problem through observation, inquiry, or directive
    b. Demonstrates ability to grasp appropriate overview and degree of seriousness of problem and to behave responsibly in situation
    c. Demonstrates ability to generate alternatives or options for problem solution
    d. Demonstrates ability to research options, assess and evaluate options, and determine appropriate and best solution
    e. Demonstrates ability to initiate and effect solution
    f. Demonstrates ability to take responsibility for outcomes
    g. Demonstrates ability to effectively problem solve in individual, team, or group situations
3. *Seeing Things In the Mind's Eye: Organizes, and processes symbols, pictures, graphs, objects, and other information*
    a. Functions at minimum or above required visual levels in order to see, interpret, attend and respond to visual imagery and meet safety requirements for necessary machinery
    b. Demonstrates ability to read, interpret, and act upon signs, symbols, and other visual cues
    c. Demonstrates ability to visually discriminate in gross and fine imagery
    d. Demonstrates ability to visualize abstractly
    e. Demonstrates ability to apply visual imagery to applied tasks
4. *Knowing How to Learn: Use efficient learning techniques to acquire and apply new knowledge and skills*
    a. Demonstrates mastery of basic reading, math, and language skills through application
    b. Demonstrates ability to translate abstract theory into practical application

        - c. Demonstrates ability to incorporate and generalize new learning into a sequential learning process
        - d. Demonstrates knowledge of good study skills and learning habits
    - *5.* ***Reasoning:*** *Discovers a rule or principle underlying the relationship between two or more objects and applies it when solving a problem*
        - a. Demonstrates use of simple logic
        - b. Demonstrates ability to distinguish relationships
        - c. Demonstrates ability to determine and isolate factors in relationships
        - d. Demonstrates and applies knowledge through practice
        - e. Recognizes that attitudes, skills, and practice are essential to productivity
        - f. Demonstrates ability to discriminate between positive and negative, and act accordingly
- C. **Personal Qualities:** Displays responsibility, self-esteem, sociability, self-management, and integrity and honesty
    - *1.* ***Responsibility:*** *Exerts a high level of effort and perseveres towards goal attainment*
        - a. Demonstrates ability to formulate realistic and useful short and long term goals and complete steps necessary to timely achieve goals
        - b. Demonstrates ability to make adjustments, revisions, and changes to achieve goals in a cooperative and polite manner
        - c. Demonstrates ability to focus on task at hand and work to completion
        - d. Demonstrates good work ethics through regular attendance, adequate classroom preparations, and appropriate use of classroom time
        - e. Demonstrates maturity to take responsibility for actions
        - f. Demonstrates ability to cooperatively work in individual, team, and group situations in timely and effective manner
    - *2.* ***Self-Esteem:*** *Believes in own self-worth and maintains a positive view of self*
        - a. Presents a positive attitude toward tasks
        - b. Demonstrates ability to separate work and personal behaviors
        - c. Actively participates in learning opportunities by sharing knowledge and skills with peers and instructors
        - d. Demonstrates ability to accept personal strengths and weaknesses and builds on positive behaviors

   - e. Demonstrates ability to accept and use constructive criticism
   - f. Accepts positive reinforcement in an appropriate manner
3. ***Sociability:** Demonstrates understanding, friendliness, adaptability, empathy, and politeness in group settings*
   - a. Demonstrates appropriate and acceptable social behaviors in interactions
   - b. Demonstrates ability to work cooperatively in individual, team, or group situations
   - c. Demonstrates active interest in peers by offering assistance, sharing resources, and sharing knowledge in a professional and acceptable manner
   - d. Demonstrates professional work ethic by separating work and personal social behaviors and acting accordingly
4. ***Self-Management:** Assesses self accurately, sets personal goals, monitors progress, and exhibits self-control*
   - a. Accepts personal strengths and weaknesses and uses the same for positive advancement
   - b. Demonstrates ability to continuously set, assess, choose, and modify objectives as the situation demands in an appropriate manner
   - c. Demonstrates ability to formulate and follow personal schedules
   - d. Demonstrates ability to wisely use classroom time
   - e. Demonstrates use of good study habits and skills
   - f. Demonstrates maturity to take responsibility for own actions
5. ***Integrity/Honesty:** Chooses ethical courses of action*
   - a. Knows and demonstrates ability to distinguish between positive and negative behaviors
   - b. Demonstrates honesty and integrity in working with peers and supervisors
   - c. Takes full responsibility for personal actions
   - d. Demonstrates understanding of consequences for negative ethical behaviors and accepts responsibility for same when applicable
   - e. Demonstrates positive work and social ethics in undertakings

Appropriate Reference Materials:

1. MASTER Technical Modules:
   CNC-B1 through CNC-B8;
   CNC-C1 through CNC-C10;

CNC-E1 through CNC-E6;
CNC-G2 through CNC-G4; and,
CNC-H1 through CNC-H5.

2. *Vericut Programming Manual,* Latest Edition
3. *N-See Programming Manual,* Latest Edition
4. *MasterCam For Windows Programming Manual,* Latest Edition
5. *SmartCam Programming Manual,* Latest Edition
6. *Anilam Program Manual,* Latest Edition
7. *Bendix Dynapath Manual,* Latest Edition
8. *Fadal Programming Manual,* Latest Edition
9. *Fanuc 6T Programming Manual,* Latest Edition
10. *Greco System Manual,* Latest Edition

CNC 181
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CNC 160

MASTER PROGRAM

Introduction to CAD/CAM

COURSE SYLLABUS

Total lecture hours: 48 **Total lab hours: 48** **Credit hours: 4**

COURSE DESCRIPTION:

Introduction to CAD/CAM theory's and software. The emphasis will be on the generation of CNC programs, at a basic level, for both CNC Mill, and CNC Lathe.

PREREQUISITES: **Introduction to CNC Verification and Communication or concurrent enrollment**

COURSE OBJECTIVES:

After successful completion of this course, the students will be able to:

1. Demonstrate the correct use of CAD/CAM software to generate basic 2 dimensional shapes;
2. Demonstrate the use of the post-processor and co-processor for intermediate CNC data;
3. Properly identify various parts of CNC program generation;
4. Perform editing of CNC programs using various software;
5. Demonstrate use of communications module within CAD/CAM software;
6. Demonstrate proper use of personal computers;
7. Demonstrate a basic understanding of the common DOS and Windows commands as used on personal computers;
8. Demonstrate reading and writing skills to read and prepare required documents for course work; and,
9. Demonstrate communication skills to interact successfully with members of working teams and instructor.

REQUIRED COURSE MATERIALS:

Textbooks: *MasterCam For Windows*, Latest Edition
Lab Manual: None

Supplies:

Computer Diskettes

METHOD OF INSTRUCTION:

Lecture:	Presentations will include lecture, with or without, various audio-visual aids; discussion, debate, and/or critique; demonstration; computer–assisted or other self-paced instruction; field trips or field assignments.
Laboratory:	Laboratory will be a hands–on process.

Method of Evaluation: A student's grade will be based on multiple measures of performance. The assessment will measure development of independent critical thinking skills and will include evaluation of the student's ability to:

1. Perform the manipulative skills of the craft as required to satisfactorily complete laboratory assignments;
2. Apply theory to laboratory assignments;
3. Satisfactorily perform on written, oral, or practical examinations;
4. Satisfactorily perform on outside assignments including writing assignments;
5. Contribute to class discussions;
6. Maintain attendance per current policy; and,
7. Follow all laboratory rules and safety regulations.

LECTURE OUTLINE:

Lecture Topics	Contact Hrs.
Basic Geometry Generation	
A. Contours	
B. Pockets	
C. Lettering	
D. Drilling	
Basic Toolpaths Generation	
A. Contours	
B. Pockets	
C. Lettering	
D. Drilling	
Tooling Parameters	
A. Definition of materials	
B. Definition of tool files	
C. Discussion of speeds, and feeds	
D. Discussion of cutting tools and geometries	
Intermediate Files	
A. Backplotting completed intermediate files	
B. Editing intermediate files	
C. Merging intermediate files	
D. Projection of intermediate files	

Generating CNC Code
A. Selection of post, or co–processors
B. Operation of post, or co–processors
C. Reverse postprocessing
Communication Parameters
A. RS–232 interface
B. Downloading
C. Uploading
D. Handshaking
E. Greco System's communication
Controls Parameters
A. Fadal Controller
B. Personal Computers
C. Anilam Control
D. Fanuc Control
E. Dynapath System 10
Personal Computers
A.. Basic terminology
B. Basic operation
C. Basic DOS commands

Total Lecture Hours **48**

LAB OUTLINE:

Lab Topics	Contact Hrs.
Basic Geometry Generation	
Basic Toolpaths Generation	
Tooling Parameters	
Intermediate Files	
Generating CNC Code	
Communication Parameters	
Controls Parameters	
Personal Computers	
Total Lab Hours	48

COURSE OBJECTIVES: SCANS COMPETENCIES

The Secretary's Commission on Achieving Necessary Skills (SCANS), U.S. Department of Labor, has identified in its "AMERICA 2000 REPORT" that all students should develop a new set of competencies and foundation skills if they are to enjoy a productive, full and satisfying life. These are in addition to the Technical Workplace Competencies required by industry. SCANS is made up of five competencies and a three-part foundation of skills and personal qualities that are needed for solid job performance.

All italicized headings in this section are direct quotations from "What Work Requires of Schools: A SCANS Report for America 2000."

The following activities will be performed by each student for successful completion of this course:

I. COMPETENCIES

- ***A. Resources: Identifies, organizes, plans, and allocates resources***
    - **1. Allocates time to complete assigned tasks on schedule**
    - **2. Determines and allocates required materials and resources for meeting objectives**
    - **3. Evaluates skills, performance, and quality of work and provides feedback**
- ***B. Interpersonal: Works with others***
    - **1. Participates as a member of the team, contributing to group effort**
    - **2. Provides individual assistance/direction to peers as requested**
    - **3. Determines and meets expectations**
    - **4. Exercises leadership qualities to effectively communicate ideas and make decisions.**
    - **5. Negotiates resources in order to accomplish objectives**
    - **6. Works well with all members of the class**
- ***C. Information: Acquires and uses information***
    - **1. Acquires and evaluates information**
    - **2. Organizes and maintains information**
    - **3. Interprets and communicates information**
- ***D. Systems: Understands complex inter-relationships***
    - **1. Understands and works well with social, organizational, and technological systems**
    - **2. Monitors and corrects performance of system during operation**
    - **3. Recommends modifications to system to improve performance**
- ***E. Technology: Works with a variety of technologies***
    - **1. Chooses relevant procedures, tools, and equipment**
    - **2. Applies appropriate procedures and techniques to accomplish tasks**
    - **3. Identifies or solves problems to maintain equipment**

II. FOUNDATION SKILLS

- **A. Basic Skills: Reads, writes, performs arithmetic and mathematical operations, listens and speaks**
    - ***1. Reading: Locates, understands, and interprets written information in prose and in documents such as manuals, graphs, and schedules***

   - a. **Demonstrates basic reading skills including abilities to perceive main ideas, draw appropriate conclusions, detect a sequence, locate answers, find facts, and infer from written texts**
   - b. **Demonstrates course specific reading skills including abilities to read, interpret, and comprehend information from text and supplemental materials on a level to facilitate productive independent and group study**
   - c. **Demonstrates ability to read, interpret, and utilize information from course specific instruments (i.e., charts, diagrams, graphs, schematics, blueprints, flow charts, etc.)**
   - d. **Demonstrates ability to read, interpret, and follow schedules and procedural instructions in a timely and appropriate manner**
   - e. **Demonstrates ability to choose and use most appropriate reading method (skim, scan, or read for comprehension) for materials**

2. ***Writing:*** *Communicates thoughts, ideas, information, and messages in writing; and creates documents such as letters, directions, manuals, reports, graphs, and flow charts*
   - a. **Demonstrates basic writing skills including abilities to produce written documents which conform with accepted grammatical and communication standards required for effective daily functioning**
   - b. **Demonstrates effective written study skills including note taking, maintaining course specific journals, workbooks, manuals, etc.**
   - c. **Demonstrates technical writing skills in preparing outlines, summaries, time lines, flow charts, diagrams, etc. appropriate to materials covered**
   - d. **Demonstrates ability to complete all required writings in a timely, complete, and professional manner**
   - e. **Demonstrates competence in subject matter through the organization and presentation of answers to required written assessments**

3. ***Arithmetic/Mathematics:*** *Perform basic computations and approaches practical problems by choosing appropriately from a variety of mathematical techniques*
   - a. **Demonstrates proficiency in basic arithmetic functions including ability to add, subtract, multiply, and divide whole numbers, fractions, decimals, and percentages**

    - b. **Demonstrates ability to read, comprehend, and select appropriate math procedures to work basic math problems**
    - c. **Demonstrates ability to understand and perform multi-step computations**
    - d. **Demonstrates ability to read, interpret, and use standard measuring devices**
    - e. **Demonstrates ability to comprehend, retain, and utilize course specific measuring devices effectively**
    - f. **Demonstrates ability to understand, retain, and utilize higher mathematical formulas and functions required for course specific math performance**
    - g. **Demonstrates ability to appropriately transfer mathematical calculations and information from paper to machines**

4. ***Listening:*** *Receives, attends to, interprets, and responds to verbal messages and other cues*
    - a. **Functions at minimal or above required hearing levels to receive, attend, interpret, and respond to verbal messages and instructions and to safely operate machinery**
    - b. **Demonstrates ability to hear, comprehend, and appropriately follow directions**
    - c. **Demonstrates auditory ability to hear, comprehend, and utilize verbal classroom as well as other auditory instruction**
    - d. **Demonstrates ability to discriminate between essential and non-essential verbal information and react appropriately**
    - e. **Demonstrates ability to focus and fine-tune listening skills to receive, interpret, and respond to various sounds**
    - f. **Demonstrates ability and maturity to seek and receive additional individualized instruction as needed**
5. ***Speaking*****:** *Organizes ideas and communicates orally*
    - a. **Demonstrates appropriate listening and speaking skills in personal conversations**
    - b. **Demonstrates ability to choose and organize appropriate words to effectively communicate**
    - c. **Demonstrates ability to speak clearly and distinctly with appropriate volume, tone, and body language for situation**
    - d. **Demonstrates ability to spontaneously organize and present appropriate answers and/or short presentations for classroom and /or assessment purposes**
    - e. **Demonstrates ability to formulate, organize, and deliver major presentations to peers or groups**

        - f. Demonstrates ability to speak effectively in one-on-one, small group, or large group presentations
        - g. Demonstrates ability to take responsibility for presentations

- B. **Thinking Skills:** Thinks creatively, makes decisions, solves problems, visualizes, knows how to learn and reasons
    - 1. ***Decision Making:*** *Specifies goals and constraints, generates alternatives, considers risks, and evaluates and chooses best alternative*
        - a. Demonstrates ability to objectively assess personal strengths and weaknesses
        - b. Demonstrates ability to set realistic short-term and long-term goals
        - c. Demonstrates ability to recognize and distinguish between positive and negative alternatives
        - d. Demonstrates ability to identify potential pitfalls and take evasive actions
        - e. Demonstrates ability to objectively and responsibly evaluate alternatives by testing hypotheses and selecting most appropriate response
        - f. Demonstrates ability to profit from negative evaluations or mistakes by reformulating, redirecting, reconstructing, or retesting alternatives
        - g. Demonstrates maturity in taking responsibility for decisions
    - 2. ***Problem Solving:*** *Recognizes problems and devises and implements plan of action*
        - a. Demonstrates ability to detect problem through observation, inquiry, or directive
        - b. Demonstrates ability to grasp appropriate overview and degree of seriousness of problem and to behave responsibly in situation
        - c. Demonstrates ability to generate alternatives or options for problem solution
        - d. Demonstrates ability to research options, assess and evaluate options, and determine appropriate and best solution
        - e. Demonstrates ability to initiate and effect solution
        - f. Demonstrates ability to take responsibility for outcomes
        - g. Demonstrates ability to effectively problem solve in individual, team, or group situations
    - 3. ***Seeing Things In the Mind's Eye:*** *Organizes, and processes symbols, pictures, graphs, objects, and other information*

        - a. Functions at minimum or above required visual levels in order to see, interpret, attend and respond to visual imagery and meet safety requirements for necessary machinery
        - b. Demonstrates ability to read, interpret, and act upon signs, symbols, and other visual cues
        - c. Demonstrates ability to visually discriminate in gross and fine imagery
        - d. Demonstrates ability to visualize abstractly
        - e. Demonstrates ability to apply visual imagery to applied tasks
    - *4.* ***Knowing How to Learn:*** *Use efficient learning techniques to acquire and apply new knowledge and skills*
        - a. Demonstrates mastery of basic reading, math, and language skills through application
        - b. Demonstrates ability to translate abstract theory into practical application
        - c. Demonstrates ability to incorporate and generalize new learning into a sequential learning process
        - d. Demonstrates knowledge of good study skills and learning habits
    - *5.* ***Reasoning:*** *Discovers a rule or principle underlying the relationship between two or more objects and applies it when solving a problem*
        - a. Demonstrates use of simple logic
        - b. Demonstrates ability to distinguish relationships
        - c. Demonstrates ability to determine and isolate factors in relationships
        - d. Demonstrates and applies knowledge through practice
        - e. Recognizes that attitudes, skills, and practice are essential to productivity
        - f. Demonstrates ability to discriminate between positive and negative, and act accordingly
- C. **Personal Qualities:** Displays responsibility, self-esteem, sociability, self-management, and integrity and honesty
    - *1.* ***Responsibility:*** *Exerts a high level of effort and perseveres towards goal attainment*
        - a. Demonstrates ability to formulate realistic and useful short and long term goals and complete steps necessary to timely achieve goals
        - b. Demonstrates ability to make adjustments, revisions, and changes to achieve goals in a cooperative and polite manner

- c. Demonstrates ability to focus on task at hand and work to completion
- d. Demonstrates good work ethics through regular attendance, adequate classroom preparations, and appropriate use of classroom time
- e. Demonstrates maturity to take responsibility for actions
- f. Demonstrates ability to cooperatively work in individual, team, and group situations in timely and effective manner

2. ***Self-Esteem:*** *Believes in own self-worth and maintains a positive view of self*
    - a. Presents a positive attitude toward tasks
    - b. Demonstrates ability to separate work and personal behaviors
    - c. Actively participates in learning opportunities by sharing knowledge and skills with peers and instructors
    - d. Demonstrates ability to accept personal strengths and weaknesses and builds on positive behaviors
    - e. Demonstrates ability to accept and use constructive criticism
    - f. Accepts positive reinforcement in an appropriate manner
3. ***Sociability:*** *Demonstrates understanding, friendliness, adaptability, empathy, and politeness in group settings*
    - a. Demonstrates appropriate and acceptable social behaviors in interactions
    - b. Demonstrates ability to work cooperatively in individual, team, or group situations
    - c. Demonstrates active interest in peers by offering assistance, sharing resources, and sharing knowledge in a professional and acceptable manner
    - d. Demonstrates professional work ethic by separating work and personal social behaviors and acting accordingly
4. ***Self-Management:*** *Assesses self accurately, sets personal goals, monitors progress, and exhibits self-control*
    - a. Accepts personal strengths and weaknesses and uses the same for positive advancement
    - b. Demonstrates ability to continuously set, assess, choose, and modify objectives as the situation demands in an appropriate manner
    - c. Demonstrates ability to formulate and follow personal schedules
    - d. Demonstrates ability to wisely use classroom time
    - e. Demonstrates use of good study habits and skills

        - f. Demonstrates maturity to take responsibility for own actions
    - 5. *Integrity/Honesty: Chooses ethical courses of action*
        - a. Knows and demonstrates ability to distinguish between positive and negative behaviors
        - b. Demonstrates honesty and integrity in working with peers and supervisors
        - c. Takes full responsibility for personal actions
        - d. Demonstrates understanding of consequences for negative ethical behaviors and accepts responsibility for same when applicable
        - e. Demonstrates positive work and social ethics in undertakings

Appropriate Reference Materials:

1. MASTER Technical Modules:
    - CNC-B1 through CNC-B8;
    - CNC-C1 through CNC-C10;
    - CNC-E1 through CNC-E6;
    - CNC-G2 through CNC-G4;
    - CNC-H1 through CNC-H5; and,
    - CNC-I1 through CNC-I5.
2. *SmartCam Programming Manual,* Latest Edition
3. *Anilam Vertical Machining Program Manual,* Latest Edition
4. *Bendix Dynapath Manual,* Latest Edition
5. *Fadal Programming Manual,* Latest Edition
6. *Fanuc 6T Programming Manual,* Latest Edition
7. *Greco System Manual,* Latest Edition
8. *SurfCam Programming Manual,* Latest Edition

CNC 160
05/011298

MASTER PROGRAM

Applications of CAD/CAM I

COURSE SYLLABUS

Total lecture hours: 0 **Total lab hours: 96** **Credit hours: 2**

COURSE DESCRIPTION:

Exercises in CAD/CAM to increase students efficiency and quality of work on the generation of CNC programs, at an intermediate level, for both CNC Mill and CNC Lathe.

PREREQUISITES:

Introduction to CNC and EDM;
Introduction to CNC Verification and Communication;
Introduction to CAD/CAM or concurrent enrollment

COURSE OBJECTIVES:

After successful completion of this course, the students will be able to:

1. Demonstrate use of CAD/CAM software to create 2 dimensional designs and required tool paths at an intermediate level of quality and quantity of projects;
2. Demonstrate the use of post-processor and co-processor for intermediate CNC data at an intermediate level;
3. Complete assigned projects using required skills with limited hands-on instruction by the instructor;
4. Perform editing of CNC programs using various software;
5. Demonstrate use of communications module within CAD/CAM software;
6. Demonstrate proper use of personal computers;
7. Demonstrate a basic understanding of the common DOS and Windows commands as used on personal computers;
8. Demonstrate increased productivity, efficiency, and independent problem solving techniques;
9. Demonstrate reading and writing skills to read and prepare required documents for course work; and,
10. Demonstrate communication skills to interact successfully with members of working teams and instructor.

REQUIRED COURSE MATERIALS:

Textbooks: *MasterCam For Windows*, Latest Edition
Lab Manual: None

Supplies:
Computer Diskettes

METHOD OF INSTRUCTION:

Laboratory: Laboratory will be a hands–on process.

Method of Evaluation: A student's grade will be based on multiple measures of performance. The assessment will measure development of independent critical thinking skills and will include evaluation of the student's ability to:.

1. Perform the manipulative skills of the craft as required to satisfactorily complete laboratory assignments;
2. Apply theory to laboratory assignments;
3. Satisfactorily perform on written, oral, or practical examinations;
4. Satisfactorily perform on outside assignments including writing assignments;
5. Contribute to class discussions;
6. Maintain attendance per current policy; and,
7. Follow all laboratory rules and safety regulations.

LAB OUTLINE:

Lab Topics	Contact Hrs.
Basic Geometry Generation	
A. Contours	
B. Pockets	
C. Lettering	
D. Drilling	
E. Ruled Shapes	
F. Swept Geometries	
G. Revolution	
H. Projection	
Basic Toolpaths Generation	
A. Contours	
B. Pockets	
C. Lettering	
D. Drilling	
E. Ruled Shapes	
F. Swept Geometries	
G. Revolution	

H. Projection

Tooling Parameters

A. Definition of materials
B. Definition of tool files
C. Discussion of speeds, and feeds
D. Discussion of cutting tools and geometries

Intermediate Files

A. Backplotting completed intermediate files
B. Editing intermediate files
C. Merging intermediate files
D. Projection of intermediate files

Generating CNC Code

A. Selection of post, or co–processors
B. Operation of post, or co–processors
C. Reverse postprocessing

Communication Parameters

A. RS–232 Interface
B. Downloading
C. Uploading
D. Handshaking
E. Greco System's Communication

Controls Parameters

A. Fadal Controller
B. Personal Computers
C. Anilam Control
D. Fanuc Control
E. Dynapath System 10

Personal Computers

A. Basic terminology
B. Basic operation
C. Basic DOS commands

Total Lab Hours **96**

COURSE OBJECTIVES: SCANS COMPETENCIES

The Secretary's Commission on Achieving Necessary Skills (SCANS), U.S. Department of Labor, has identified in its "AMERICA 2000 REPORT" that all students should develop a new set of competencies and foundation skills if they are to enjoy a productive, full and satisfying life. These are in addition to the Technical Workplace Competencies required by industry. SCANS is made up of five competencies and a three-part foundation of skills and personal qualities that are needed for solid job performance. All italicized headings in this section are direct quotations from "What Work Requires of Schools: A SCANS Report for America 2000."

The following activities will be performed by each student for successful completion of this course:

I. COMPETENCIES
  - *A.* ***Resources:*** *Identifies, organizes, plans, and allocates resources*
    1. Allocates time to complete assigned tasks on schedule
    2. Determines and allocates required materials and resources for meeting objectives
    3. Evaluates skills, performance, and quality of work and provides feedback
  - *B.* ***Interpersonal:*** *Works with others*
    1. Participates as a member of the team, contributing to group effort
    2. Provides individual assistance/direction to peers as requested
    3. Determines and meets expectations
    4. Exercises leadership qualities to effectively communicate ideas and make decisions.
    5. Negotiates resources in order to accomplish objectives
    6. Works well with all members of the class
  - *C.* ***Information:*** *Acquires and uses information*
    1. Acquires and evaluates information
    2. Organizes and maintains information
    3. Interprets and communicates information
  - *D.* ***Systems:*** *Understands complex inter-relationships*
    1. Understands and works well with social, organizational, and technological systems
    2. Monitors and corrects performance of system during operation
    3. Recommends modifications to system to improve performance
  - *E.* ***Technology:*** *Works with a variety of technologies*
    1. Chooses relevant procedures, tools, and equipment
    2. Applies appropriate procedures and techniques to accomplish tasks
    3. Identifies or solves problems to maintain equipment

II. FOUNDATION SKILLS
  - A. Basic Skills: Reads, writes, performs arithmetic and mathematical operations, listens and speaks
    - *1.* ***Reading:*** *Locates, understands, and interprets written information in prose and in documents such as manuals, graphs, and schedules*
      - a. Demonstrates basic reading skills including abilities to perceive main ideas, draw appropriate conclusions, detect

a sequence, locate answers, find facts, and infer from written texts

    b. Demonstrates course specific reading skills including abilities to read, interpret, and comprehend information from text and supplemental materials on a level to facilitate productive independent and group study
    c. Demonstrates ability to read, interpret, and utilize information from course specific instruments (i.e., charts, diagrams, graphs, schematics, blueprints, flow charts, etc.)
    d. Demonstrates ability to read, interpret, and follow schedules and procedural instructions in a timely and appropriate manner
    e. Demonstrates ability to choose and use most appropriate reading method (skim, scan, or read for comprehension) for materials

2. *Writing: Communicates thoughts, ideas, information, and messages in writing; and creates documents such as letters, directions, manuals, reports, graphs, and flow charts*
    a. Demonstrates basic writing skills including abilities to produce written documents which conform with accepted grammatical and communication standards required for effective daily functioning
    b. Demonstrates effective written study skills including note taking, maintaining course specific journals, workbooks, manuals, etc.
    c. Demonstrates technical writing skills in preparing outlines, summaries, time lines, flow charts, diagrams, etc. appropriate to materials covered
    d. Demonstrates ability to complete all required writings in a timely, complete, and professional manner
    e. Demonstrates competence in subject matter through the organization and presentation of answers to required written assessments

3. *Arithmetic/Mathematics: Perform basic computations and approaches practical problems by choosing appropriately from a variety of mathematical techniques*
    a. Demonstrates proficiency in basic arithmetic functions including ability to add, subtract, multiply, and divide whole numbers, fractions, decimals, and percentages
    b. Demonstrates ability to read, comprehend, and select appropriate math procedures to work basic math problems

- c. Demonstrates ability to understand and perform multi-step computations
- d. Demonstrates ability to read, interpret, and use standard measuring devices
- e. Demonstrates ability to comprehend, retain, and utilize course specific measuring devices effectively
- f. Demonstrates ability to understand, retain, and utilize higher mathematical formulas and functions required for course specific math performance
- g. Demonstrates ability to appropriately transfer mathematical calculations and information from paper to machines

4. ***Listening:*** *Receives, attends to, interprets, and responds to verbal messages and other cues*
   - a. Functions at minimal or above required hearing levels to receive, attend, interpret, and respond to verbal messages and instructions and to safely operate machinery
   - b. Demonstrates ability to hear, comprehend, and appropriately follow directions
   - c. Demonstrates auditory ability to hear, comprehend, and utilize verbal classroom as well as other auditory instruction
   - d. Demonstrates ability to discriminate between essential and non-essential verbal information and react appropriately
   - e. Demonstrates ability to focus and fine-tune listening skills to receive, interpret, and respond to various sounds
   - f. Demonstrates ability and maturity to seek and receive additional individualized instruction as needed
5. ***Speaking***: *Organizes ideas and communicates orally*
   - a. Demonstrates appropriate listening and speaking skills in personal conversations
   - b. Demonstrates ability to choose and organize appropriate words to effectively communicate
   - c. Demonstrates ability to speak clearly and distinctly with appropriate volume, tone, and body language for situation
   - d. Demonstrates ability to spontaneously organize and present appropriate answers and/or short presentations for classroom and /or assessment purposes
   - e. Demonstrates ability to formulate, organize, and deliver major presentations to peers or groups
   - f. Demonstrates ability to speak effectively in one-on-one, small group, or large group presentations

        g. Demonstrates ability to take responsibility for presentations

B. **Thinking Skills:** Thinks creatively, makes decisions, solves problems, visualizes, knows how to learn and reasons

1. ***Decision Making:*** *Specifies goals and constraints, generates alternatives, considers risks, and evaluates and chooses best alternative*
    - a. Demonstrates ability to objectively assess personal strengths and weaknesses
    - b. Demonstrates ability to set realistic short-term and long-term goals
    - c. Demonstrates ability to recognize and distinguish between positive and negative alternatives
    - d. Demonstrates ability to identify potential pitfalls and take evasive actions
    - e. Demonstrates ability to objectively and responsibly evaluate alternatives by testing hypotheses and selecting most appropriate response
    - f. Demonstrates ability to profit from negative evaluations or mistakes by reformulating, redirecting, reconstructing, or retesting alternatives
    - g. Demonstrates maturity in taking responsibility for decisions
2. ***Problem Solving:*** *Recognizes problems and devises and implements plan of action*
    - a. Demonstrates ability to detect problem through observation, inquiry, or directive
    - b. Demonstrates ability to grasp appropriate overview and degree of seriousness of problem and to behave responsibly in situation
    - c. Demonstrates ability to generate alternatives or options for problem solution
    - d. Demonstrates ability to research options, assess and evaluate options, and determine appropriate and best solution
    - e. Demonstrates ability to initiate and effect solution
    - f. Demonstrates ability to take responsibility for outcomes
    - g. Demonstrates ability to effectively problem solve in individual, team, or group situations
3. ***Seeing Things In the Mind's Eye:*** *Organizes, and processes symbols, pictures, graphs, objects, and other information*
    - a. Functions at minimum or above required visual levels in order to see, interpret, attend and respond to visual

        imagery and meet safety requirements for necessary machinery
        b. Demonstrates ability to read, interpret, and act upon signs, symbols, and other visual cues
        c. Demonstrates ability to visually discriminate in gross and fine imagery
        d. Demonstrates ability to visualize abstractly
        e. Demonstrates ability to apply visual imagery to applied tasks
    4. ***Knowing How to Learn:*** *Use efficient learning techniques to acquire and apply new knowledge and skills*
        a. Demonstrates mastery of basic reading, math, and language skills through application
        b. Demonstrates ability to translate abstract theory into practical application
        c. Demonstrates ability to incorporate and generalize new learning into a sequential learning process
        d. Demonstrates knowledge of good study skills and learning habits
    5. ***Reasoning:*** *Discovers a rule or principle underlying the relationship between two or more objects and applies it when solving a problem*
        a. Demonstrates use of simple logic
        b. Demonstrates ability to distinguish relationships
        c. Demonstrates ability to determine and isolate factors in relationships
        d. Demonstrates and applies knowledge through practice
        e. Recognizes that attitudes, skills, and practice are essential to productivity
        f. Demonstrates ability to discriminate between positive and negative, and act accordingly

C. **Personal Qualities:** Displays responsibility, self-esteem, sociability, self-management, and integrity and honesty
    1. ***Responsibility:*** *Exerts a high level of effort and perseveres towards goal attainment*
        a. Demonstrates ability to formulate realistic and useful short and long term goals and complete steps necessary to timely achieve goals
        b. Demonstrates ability to make adjustments, revisions, and changes to achieve goals in a cooperative and polite manner
        c. Demonstrates ability to focus on task at hand and work to completion

- d. Demonstrates good work ethics through regular attendance, adequate classroom preparations, and appropriate use of classroom time
- e. Demonstrates maturity to take responsibility for actions
- f. Demonstrates ability to cooperatively work in individual, team, and group situations in timely and effective manner

2. ***Self-Esteem:*** *Believes in own self-worth and maintains a positive view of self*

- a. Presents a positive attitude toward tasks
- b. Demonstrates ability to separate work and personal behaviors
- c. Actively participates in learning opportunities by sharing knowledge and skills with peers and instructors
- d. Demonstrates ability to accept personal strengths and weaknesses and builds on positive behaviors
- e. Demonstrates ability to accept and use constructive criticism
- f. Accepts positive reinforcement in an appropriate manner

3. ***Sociability:*** *Demonstrates understanding, friendliness, adaptability, empathy, and politeness in group settings*

- a. Demonstrates appropriate and acceptable social behaviors in interactions
- b. Demonstrates ability to work cooperatively in individual, team, or group situations
- c. Demonstrates active interest in peers by offering assistance, sharing resources, and sharing knowledge in a professional and acceptable manner
- d. Demonstrates professional work ethic by separating work and personal social behaviors and acting accordingly

4. ***Self-Management:*** *Assesses self accurately, sets personal goals, monitors progress, and exhibits self-control*

- a. Accepts personal strengths and weaknesses and uses the same for positive advancement
- b. Demonstrates ability to continuously set, assess, choose, and modify objectives as the situation demands in an appropriate manner
- c. Demonstrates ability to formulate and follow personal schedules
- d. Demonstrates ability to wisely use classroom time
- e. Demonstrates use of good study habits and skills
- f. Demonstrates maturity to take responsibility for own actions

5. ***Integrity/Honesty:*** *Chooses ethical courses of action*

- a. Knows and demonstrates ability to distinguish between positive and negative behaviors
- b. Demonstrates honesty and integrity in working with peers and supervisors
- c. Takes full responsibility for personal actions
- d. Demonstrates understanding of consequences for negative ethical behaviors and accepts responsibility for same when applicable
- e. Demonstrates positive work and social ethics in undertakings

Appropriate Reference Materials:

1. MASTER Technical Modules:
    - CNC-B1 through CNC-B8;
    - CNC-C1 through CNC-C10;
    - CNC-E1 through CNC-E6;
    - CNC-G2 through CNC-G4;
    - CNC-H1 through CNC-H5; and,
    - CNC-I1 through CNC-I5.
2. *SmartCam Programming Manuals,* Latest Edition
3. *Anilam Vertical Machining Program Manual,* Latest Edition
4. *Bendix Dynapath Manual,* Latest Edition
5. *Fadal Programming Manual,* Latest Edition
6. *Fanuc 6T Programming Manual,* Latest Edition
7. *Greco Systems Manual,* Latest Edition
8. *SurfCam Programming Manual,* Latest Edition

CNC 161
06/011298

MASTER PROGRAM

Introduction to CNC Controlled Vertical Machining and Electronic Discharge Machining (EDM)

COURSE SYLLABUS

Total lecture hours: 48 **Total lab hours: 48** **Credit hours: 4**

COURSE DESCRIPTION:

Theory of CNC Vertical machining techniques. Emphasis placed on basic operations of Vertical Machining, and EDM. Students in this class are expected to have previous Machining experience.

PREREQUISITES: **Introduction to CNC and EDM or concurrent enrollment**

COURSE OBJECTIVES:

After successful completion of this course, the students will be able to:
1. Identify CNC Mills and their controls and accessories;
2. Use charts, reference tables, math calculations to determine speeds and feeds;
3. Demonstrate the proper set up procedures for the Anilam, Bridgeport, and Fadal;
4. Demonstrate proper use of Controller to set offsets, edit programs, and create programs at the Controller;
5. Demonstrate a basic understanding of the common "G" and "M" codes as used on CNC machines to create various programs;
6. Complete assigned projects using required skills with hands-on instruction by the instructor;
7. Demonstrate reading and writing skills to read and prepare required documents for course work; and,
8. Demonstrate communication skills to interact successfully with members of working teams and instructor.

REQUIRED COURSE MATERIALS:

Textbooks:
Technology of Machine Tools, Latest Edition
Fundamentals of Numerical Control, Latest Edition
Computer Numerical Control: From Programming to Networking, Latest Edition

Lab Manual: None

Supplies:
Computer Diskettes

METHOD OF INSTRUCTION

Lecture: Presentations will include lecture, with or without various audio-visual aids; discussion, debate, and/or critique; demonstration; computer–assisted or other self–paced instruction; field trips or field assignments.

Laboratory: Laboratory will be a hands–on process utilizing specifically planned instructional activities or "live" work..

Method of Evaluation: A student's grade will be based on multiple measures of performance. The assessment will measure development of independent critical thinking skills and will include evaluation of the student's ability to:

1. Perform the manipulative skills of the craft as required to satisfactorily complete laboratory assignments;
2. Apply theory to laboratory assignments;
3. Satisfactorily perform on written, oral, or practical examinations;
4. Satisfactorily perform on outside assignments including writing assignments;
5. Contribute to class discussions;
6. Maintain attendance per current policy; and,
7. Follow all laboratory rules and safety regulations.

LECTURE OUTLINE:

Lecture Topics	Contact Hrs.
CNC Vertical Machining	
A. History	
B. Theory of operation	
C. Nomenclature	
D. Safety	
E. Controller commands	
F. Discussion of "canned cycles"	
G. Tooling setup	
H. Tooling offsets	
I. Editing programs	
Controls	
A. Anilam control	
B. Bridgeport control	
C. Fadal control	

D. Greco System for creating programs
E. Hansvedt Control Panel

Electronic Discharge Machining

A. History
B. Theory of operation
C. Nomenclature
D. Safety
E. Controller settings
F. Tooling setup
G. Tooling materials

Total Lecture Hours **48**

LAB OUTLINE:

Lab Topics	Contact Hrs.
CNC Vertical Machining	
Controls	
Electronic Discharge Machining	
Total Lab Hours	**48**

COURSE OBJECTIVES: SCANS COMPETENCIES

The Secretary's Commission on Achieving Necessary Skills (SCANS), U.S. Department of Labor, has identified in its "AMERICA 2000 REPORT" that all students should develop a new set of competencies and foundation skills if they are to enjoy a productive, full and satisfying life. These are in addition to the Technical Workplace Competencies required by industry. SCANS is made up of five competencies and a three-part foundation of skills and personal qualities that are needed for solid job performance. All italicized headings in this section are direct quotations from "What Work Requires of Schools: A SCANS Report for America 2000."

The following activities will be performed by each student for successful completion of this course:

I. COMPETENCIES
  A. *Resources: Identifies, organizes, plans, and allocates resources*
    1. Allocates time to complete assigned tasks on schedule
    2. Determines and allocates required materials and resources for meeting objectives
    3. Evaluates skills, performance, and quality of work and provides feedback
  B. *Interpersonal: Works with others*

    1. Participates as a member of the team, contributing to group effort
    2. Provides individual assistance/direction to peers as requested
    3. Determines and meets expectations
    4. Exercises leadership qualities to effectively communicate ideas and make decisions.
    5. Negotiates resources in order to accomplish objectives
    6. Works well with all members of the class

C. *Information: Acquires and uses information*
    1. Acquires and evaluates information
    2. Organizes and maintains information
    3. Interprets and communicates information

D. *Systems: Understands complex inter-relationships*
    1. Understands and works well with social, organizational, and technological systems
    2. Monitors and corrects performance of system during operation
    3. Recommends modifications to system to improve performance

E. *Technology: Works with a variety of technologies*
    1. Chooses relevant procedures, tools, and equipment
    2. Applies appropriate procedures and techniques to accomplish tasks
    3. Identifies or solves problems to maintain equipment

II. FOUNDATION SKILLS

A. **Basic Skills:** Reads, writes, performs arithmetic and mathematical operations, listens and speaks
    1. ***Reading:*** *Locates, understands, and interprets written information in prose and in documents such as manuals, graphs, and schedules*
        a. Demonstrates basic reading skills including abilities to perceive main ideas, draw appropriate conclusions, detect a sequence, locate answers, find facts, and infer from written texts
        b. Demonstrates course specific reading skills including abilities to read, interpret, and comprehend information from text and supplemental materials on a level to facilitate productive independent and group study
        c. Demonstrates ability to read, interpret, and utilize information from course specific instruments (i.e., charts, diagrams, graphs, schematics, blueprints, flow charts, etc.)
        d. Demonstrates ability to read, interpret, and follow schedules and procedural instructions in a timely and appropriate manner

    e. Demonstrates ability to choose and use most appropriate reading method (skim, scan, or read for comprehension) for materials

2. ***Writing:*** *Communicates thoughts, ideas, information, and messages in writing; and creates documents such as letters, directions, manuals, reports, graphs, and flow charts*
    a. Demonstrates basic writing skills including abilities to produce written documents which conform with accepted grammatical and communication standards required for effective daily functioning
    b. Demonstrates effective written study skills including note taking, maintaining course specific journals, workbooks, manuals, etc.
    c. Demonstrates technical writing skills in preparing outlines, summaries, time lines, flow charts, diagrams, etc. appropriate to materials covered
    d. Demonstrates ability to complete all required writings in a timely, complete, and professional manner
    e. Demonstrates competence in subject matter through the organization and presentation of answers to required written assessments
3. ***Arithmetic/Mathematics:*** *Perform basic computations and approaches practical problems by choosing appropriately from a variety of mathematical techniques*
    a. Demonstrates proficiency in basic arithmetic functions including ability to add, subtract, multiply, and divide whole numbers, fractions, decimals, and percentages
    b. Demonstrates ability to read, comprehend, and select appropriate math procedures to work basic math problems
    c. Demonstrates ability to understand and perform multi-step computations
    d. Demonstrates ability to read, interpret, and use standard measuring devices
    e. Demonstrates ability to comprehend, retain, and utilize course specific measuring devices effectively
    f. Demonstrates ability to understand, retain, and utilize higher mathematical formulas and functions required for course specific math performance
    g. Demonstrates ability to appropriately transfer mathematical calculations and information from paper to machines
4. ***Listening:*** *Receives, attends to, interprets, and responds to verbal messages and other cues*

- a. Functions at minimal or above required hearing levels to receive, attend, interpret, and respond to verbal messages and instructions and to safely operate machinery
- b. Demonstrates ability to hear, comprehend, and appropriately follow directions
- c. Demonstrates auditory ability to hear, comprehend, and utilize verbal classroom as well as other auditory instruction
- d. Demonstrates ability to discriminate between essential and non-essential verbal information and react appropriately
- e. Demonstrates ability to focus and fine-tune listening skills to receive, interpret, and respond to various sounds
- f. Demonstrates ability and maturity to seek and receive additional individualized instruction as needed

5. ***Speaking**: Organizes ideas and communicates orally*

- a. Demonstrates appropriate listening and speaking skills in personal conversations
- b. Demonstrates ability to choose and organize appropriate words to effectively communicate
- c. Demonstrates ability to speak clearly and distinctly with appropriate volume, tone, and body language for situation
- d. Demonstrates ability to spontaneously organize and present appropriate answers and/or short presentations for classroom and /or assessment purposes
- e. Demonstrates ability to formulate, organize, and deliver major presentations to peers or groups
- f. Demonstrates ability to speak effectively in one-on-one, small group, or large group presentations
- g. Demonstrates ability to take responsibility for presentations

B. **Thinking Skills:** Thinks creatively, makes decisions, solves problems, visualizes, knows how to learn and reasons

1. ***Decision Making:** Specifies goals and constraints, generates alternatives, considers risks, and evaluates and chooses best alternative*

- a. Demonstrates ability to objectively assess personal strengths and weaknesses
- b. Demonstrates ability to set realistic short-term and long-term goals
- c. Demonstrates ability to recognize and distinguish between positive and negative alternatives
- d. Demonstrates ability to identify potential pitfalls and take evasive actions

   - e. Demonstrates ability to objectively and responsibly evaluate alternatives by testing hypotheses and selecting most appropriate response
   - f. Demonstrates ability to profit from negative evaluations or mistakes by reformulating, redirecting, reconstructing, or retesting alternatives
   - g. Demonstrates maturity in taking responsibility for decisions

2. ***Problem Solving:*** *Recognizes problems and devises and implements plan of action*
   - a. Demonstrates ability to detect problem through observation, inquiry, or directive
   - b. Demonstrates ability to grasp appropriate overview and degree of seriousness of problem and to behave responsibly in situation
   - c. Demonstrates ability to generate alternatives or options for problem solution
   - d. Demonstrates ability to research options, assess and evaluate options, and determine appropriate and best solution
   - e. Demonstrates ability to initiate and effect solution
   - f. Demonstrates ability to take responsibility for outcomes
   - g. Demonstrates ability to effectively problem solve in individual, team, or group situations

3. ***Seeing Things In the Mind's Eye:*** *Organizes, and processes symbols, pictures, graphs, objects, and other information*
   - a. Functions at minimum or above required visual levels in order to see, interpret, attend and respond to visual imagery and meet safety requirements for necessary machinery
   - b. Demonstrates ability to read, interpret, and act upon signs, symbols, and other visual cues
   - c. Demonstrates ability to visually discriminate in gross and fine imagery
   - d. Demonstrates ability to visualize abstractly
   - e. Demonstrates ability to apply visual imagery to applied tasks

4. ***Knowing How to Learn:*** *Use efficient learning techniques to acquire and apply new knowledge and skills*
   - a. Demonstrates mastery of basic reading, math, and language skills through application
   - b. Demonstrates ability to translate abstract theory into practical application

        - c. Demonstrates ability to incorporate and generalize new learning into a sequential learning process
        - d. Demonstrates knowledge of good study skills and learning habits
    - 5. ***Reasoning:*** *Discovers a rule or principle underlying the relationship between two or more objects and applies it when solving a problem*
        - a. Demonstrates use of simple logic
        - b. Demonstrates ability to distinguish relationships
        - c. Demonstrates ability to determine and isolate factors in relationships
        - d. Demonstrates and applies knowledge through practice
        - e. Recognizes that attitudes, skills, and practice are essential to productivity
        - f. Demonstrates ability to discriminate between positive and negative, and act accordingly
- C. **Personal Qualities:** Displays responsibility, self-esteem, sociability, self-management, and integrity and honesty
    - 1. ***Responsibility:*** *Exerts a high level of effort and perseveres towards goal attainment*
        - a. Demonstrates ability to formulate realistic and useful short and long term goals and complete steps necessary to timely achieve goals
        - b. Demonstrates ability to make adjustments, revisions, and changes to achieve goals in a cooperative and polite manner
        - c. Demonstrates ability to focus on task at hand and work to completion
        - d. Demonstrates good work ethics through regular attendance, adequate classroom preparations, and appropriate use of classroom time
        - e. Demonstrates maturity to take responsibility for actions
        - f. Demonstrates ability to cooperatively work in individual, team, and group situations in timely and effective manner
    - 2. ***Self-Esteem:*** *Believes in own self-worth and maintains a positive view of self*
        - a. Presents a positive attitude toward tasks
        - b. Demonstrates ability to separate work and personal behaviors
        - c. Actively participates in learning opportunities by sharing knowledge and skills with peers and instructors
        - d. Demonstrates ability to accept personal strengths and weaknesses and builds on positive behaviors

   - e. Demonstrates ability to accept and use constructive criticism
   - f. Accepts positive reinforcement in an appropriate manner

3. *Sociability: Demonstrates understanding, friendliness, adaptability, empathy, and politeness in group settings*
   - a. Demonstrates appropriate and acceptable social behaviors in interactions
   - b. Demonstrates ability to work cooperatively in individual, team, or group situations
   - c. Demonstrates active interest in peers by offering assistance, sharing resources, and sharing knowledge in a professional and acceptable manner
   - d. Demonstrates professional work ethic by separating work and personal social behaviors and acting accordingly

4. *Self-Management: Assesses self accurately, sets personal goals, monitors progress, and exhibits self-control*
   - a. Accepts personal strengths and weaknesses and uses the same for positive advancement
   - b. Demonstrates ability to continuously set, assess, choose, and modify objectives as the situation demands in an appropriate manner
   - c. Demonstrates ability to formulate and follow personal schedules
   - d. Demonstrates ability to wisely use classroom time
   - e. Demonstrates use of good study habits and skills
   - f. Demonstrates maturity to take responsibility for own actions

5. *Integrity/Honesty: Chooses ethical courses of action*
   - a. Knows and demonstrates ability to distinguish between positive and negative behaviors
   - b. Demonstrates honesty and integrity in working with peers and supervisors
   - c. Takes full responsibility for personal actions
   - d. Demonstrates understanding of consequences for negative ethical behaviors and accepts responsibility for same when applicable
   - e. Demonstrates positive work and social ethics in undertakings

Appropriate Reference Materials:

1. MASTER Technical Modules:
   CNC-A1 through CNC-A5;
   CNC-B1 through CNC-B8;

    CNC-C1 through CNC-C10;
    CNC-E1 through CNC-E6;
    CNC-G1 through CNC-G4; and,
    CNC-H1 through CNC-H5.

2. *Anilam Vertical Machining Program Manual*, Latest Edition
3. *Fadal Programming Manual*, Latest Edition
4. *Bridgeport Programming Manual*, Latest Edition
5. *Greco Systems Manual*, Latest Edition
6. *Hansvedt Operating Manual*, Latest Edition

CNC 170
05/011298

MASTER PROGRAM

Application of CNC Controlled Vertical Machining and Electronic Discharge Machining (EDM) I

COURSE SYLLABUS

Total lecture hours: 0 **Total lab hours: 96** **Credit hours: 2**

COURSE DESCRIPTION:

Exercises in CNC Vertical machining techniques and EDM at an intermediate level. This class is to allow students the opportunity to gain speed and efficiency in a hands on environment. Students in this class are expected to have previous machining experience.

PREREQUISITES: **Introduction to CNC Controlled Vertical; Machining and Electronic Discharge; Machining (EDM) or concurrent enrollment**

COURSE OBJECTIVES:

After successful completion of this course, the students will be able to:

1. Use verification software to analyze the effects of speeds and feeds, depth of cut and total volume of material removed with intermediate level of quality and quantity of projects;
2. Demonstrate the proper set up procedures for the Anilam, Bridgeport, and Fadal using fixture offsets, multiple vises and TS–20 probe;
3. Demonstrate proper use of controller to set offsets, edit programs, and create programs at the controller with intermediate level of quality and quantity of projects;
4. Demonstrate a basic understanding of the common "G" and "M" codes as used on CNC machines to create various programs;
5. Complete assigned projects using required skills with limited hands-on instruction by the instructor;
6. Demonstrate reading and writing skills to read and prepare required documents for course work; and,
7. Demonstrate communication skills to interact successfully with members of working teams and instructor.

REQUIRED COURSE MATERIALS:

Textbooks: *Technology of Machine Tools,* Latest Edition, or

Fundamentals of Numerical Control, W. Luggen, Latest Edition, or
Computer Numerical Control: From Programming to Networking, Latest Edition

Lab Manual: None

Supplies:
Computer Diskettes

METHOD OF INSTRUCTION:

Lecture: Presentations will include lecture, with or without various audio–visual aids; discussion, debate, and/or critique; demonstration; computer–assisted or other self–paced instruction; field trips or field assignments.

Laboratory: Laboratory will be a hands–on process.

Method of Evaluation: A student's grade will be based on multiple measures of performance. The assessment will measure development of independent critical thinking skills and will include evaluation of the student's ability to:

1. Perform the manipulative skills of the craft as required to satisfactorily complete laboratory assignments;
2. Apply theory to laboratory assignments;
3. Satisfactorily perform on written, oral, or practical examinations;
4. Satisfactorily perform on outside assignments including writing assignments;
5. Contribute to class discussions;
6. Maintain attendance per current policy; and,
7. Follow all laboratory rules and safety regulations.

LAB OUTLINE:

Lab Topics	Contact Hrs.
CNC Vertical Machining	
A. History	
B. Theory of operation	
C. Nomenclature	
D. Safety	
E. Controller commands	
F. Discussion of "canned cycles"	
G. Tooling setup	
H. Tooling offsets	
I. Editing programs	
Controls	

A. Anilam Control
B. Bridgeport Control
C. Fadal Control
D. Greco System for creating programs

Electronic Discharge Machining

A. History
B. Theory of operation
C. Nomenclature
D. Safety
E. Controller settings
F. Tooling setup
G. Tooling materials

Total Lab Hours	**96**

COURSE OBJECTIVES: SCANS COMPETENCIES

The Secretary's Commission on Achieving Necessary Skills (SCANS), U.S. Department of Labor, has identified in its "AMERICA 2000 REPORT" that all students should develop a new set of competencies and foundation skills if they are to enjoy a productive, full and satisfying life. These are in addition to the Technical Workplace Competencies required by industry. SCANS is made up of five competencies and a three-part foundation of skills and personal qualities that are needed for solid job performance. All italicized headings in this section are direct quotations from "What Work Requires of Schools: A SCANS Report for America 2000."

The following activities will be performed by each student for successful completion of this course:

I. COMPETENCIES
   - *A. Resources: Identifies, organizes, plans, and allocates resources*
     1. Allocates time to complete assigned tasks on schedule
     2. Determines and allocates required materials and resources for meeting objectives
     3. Evaluates skills, performance, and quality of work and provides feedback
   - *B. Interpersonal: Works with others*
     1. Participates as a member of the team, contributing to group effort
     2. Provides individual assistance/direction to peers as requested
     3. Determines and meets expectations
     4. Exercises leadership qualities to effectively communicate ideas and make decisions.

    5. Negotiates resources in order to accomplish objectives
    6. Works well with all members of the class

C. *Information: Acquires and uses information*
    1. Acquires and evaluates information
    2. Organizes and maintains information
    3. Interprets and communicates information

D. *Systems: Understands complex inter-relationships*
    1. Understands and works well with social, organizational, and technological systems
    2. Monitors and corrects performance of system during operation
    3. Recommends modifications to system to improve performance

E. *Technology: Works with a variety of technologies*
    1. Chooses relevant procedures, tools, and equipment
    2. Applies appropriate procedures and techniques to accomplish tasks
    3. Identifies or solves problems to maintain equipment

II. FOUNDATION SKILLS

A. **Basic Skills:** Reads, writes, performs arithmetic and mathematical operations, listens and speaks

1. Reading: Locates, understands, and interprets written information in prose and in documents such as manuals, graphs, and schedules

- a. Demonstrates basic reading skills including abilities to perceive main ideas, draw appropriate conclusions, detect a sequence, locate answers, find facts, and infer from written texts
- b. Demonstrates course specific reading skills including abilities to read, interpret, and comprehend information from text and supplemental materials on a level to facilitate productive independent and group study
- c. Demonstrates ability to read, interpret, and utilize information from course specific instruments (i.e., charts, diagrams, graphs, schematics, blueprints, flow charts, etc.)
- d. Demonstrates ability to read, interpret, and follow schedules and procedural instructions in a timely and appropriate manner
- e. Demonstrates ability to choose and use most appropriate reading method (skim, scan, or read for comprehension) for materials

2. Writing: Communicates thoughts, ideas, information, and messages in writing; and creates documents such as letters, directions, manuals, reports, graphs, and flow charts

    a. Demonstrates basic writing skills including abilities to produce written documents which conform with accepted grammatical and communication standards required for effective daily functioning
    b. Demonstrates effective written study skills including note taking, maintaining course specific journals, workbooks, manuals, etc.
    c. Demonstrates technical writing skills in preparing outlines, summaries, time lines, flow charts, diagrams, etc. appropriate to materials covered
    d. Demonstrates ability to complete all required writings in a timely, complete, and professional manner
    e. Demonstrates competence in subject matter through the organization and presentation of answers to required written assessments

3. ***Arithmetic/Mathematics:*** *Perform basic computations and approaches practical problems by choosing appropriately from a variety of mathematical techniques*
    a. Demonstrates proficiency in basic arithmetic functions including ability to add, subtract, multiply, and divide whole numbers, fractions, decimals, and percentages
    b. Demonstrates ability to read, comprehend, and select appropriate math procedures to work basic math problems
    c. Demonstrates ability to understand and perform multi-step computations
    d. Demonstrates ability to read, interpret, and use standard measuring devices
    e. Demonstrates ability to comprehend, retain, and utilize course specific measuring devices effectively
    f. Demonstrates ability to understand, retain, and utilize higher mathematical formulas and functions required for course specific math performance
    g. Demonstrates ability to appropriately transfer mathematical calculations and information from paper to machines

4. ***Listening:*** *Receives, attends to, interprets, and responds to verbal messages and other cues*
    a. Functions at minimal or above required hearing levels to receive, attend, interpret, and respond to verbal messages and instructions and to safely operate machinery
    b. Demonstrates ability to hear, comprehend, and appropriately follow directions

        - c. Demonstrates auditory ability to hear, comprehend, and utilize verbal classroom as well as other auditory instruction
        - d. Demonstrates ability to discriminate between essential and non-essential verbal information and react appropriately
        - e. Demonstrates ability to focus and fine-tune listening skills to receive, interpret, and respond to various sounds
        - f. Demonstrates ability and maturity to seek and receive additional individualized instruction as needed
    - *5.* ***Speaking*: *Organizes ideas and communicates orally***
        - a. Demonstrates appropriate listening and speaking skills in personal conversations
        - b. Demonstrates ability to choose and organize appropriate words to effectively communicate
        - c. Demonstrates ability to speak clearly and distinctly with appropriate volume, tone, and body language for situation
        - d. Demonstrates ability to spontaneously organize and present appropriate answers and/or short presentations for classroom and /or assessment purposes
        - e. Demonstrates ability to formulate, organize, and deliver major presentations to peers or groups
        - f. Demonstrates ability to speak effectively in one-on-one, small group, or large group presentations
        - g. Demonstrates ability to take responsibility for presentations
- **B. Thinking Skills:** Thinks creatively, makes decisions, solves problems, visualizes, knows how to learn and reasons
    - *1.* ***Decision Making:*** *Specifies goals and constraints, generates alternatives, considers risks, and evaluates and chooses best alternative*
        - a. Demonstrates ability to objectively assess personal strengths and weaknesses
        - b. Demonstrates ability to set realistic short-term and long-term goals
        - c. Demonstrates ability to recognize and distinguish between positive and negative alternatives
        - d. Demonstrates ability to identify potential pitfalls and take evasive actions
        - e. Demonstrates ability to objectively and responsibly evaluate alternatives by testing hypotheses and selecting most appropriate response

f. Demonstrates ability to profit from negative evaluations or mistakes by reformulating, redirecting, reconstructing, or retesting alternatives
g. Demonstrates maturity in taking responsibility for decisions

2. *Problem Solving: Recognizes problems and devises and implements plan of action*
    a. Demonstrates ability to detect problem through observation, inquiry, or directive
    b. Demonstrates ability to grasp appropriate overview and degree of seriousness of problem and to behave responsibly in situation
    c. Demonstrates ability to generate alternatives or options for problem solution
    d. Demonstrates ability to research options, assess and evaluate options, and determine appropriate and best solution
    e. Demonstrates ability to initiate and effect solution
    f. Demonstrates ability to take responsibility for outcomes
    g. Demonstrates ability to effectively problem solve in individual, team, or group situations
3. *Seeing Things In the Mind's Eye: Organizes, and processes symbols, pictures, graphs, objects, and other information*
    a. Functions at minimum or above required visual levels in order to see, interpret, attend and respond to visual imagery and meet safety requirements for necessary machinery
    b. Demonstrates ability to read, interpret, and act upon signs, symbols, and other visual cues
    c. Demonstrates ability to visually discriminate in gross and fine imagery
    d. Demonstrates ability to visualize abstractly
    e. Demonstrates ability to apply visual imagery to applied tasks
4. *Knowing How to Learn: Use efficient learning techniques to acquire and apply new knowledge and skills*
    a. Demonstrates mastery of basic reading, math, and language skills through application
    b. Demonstrates ability to translate abstract theory into practical application
    c. Demonstrates ability to incorporate and generalize new learning into a sequential learning process
    d. Demonstrates knowledge of good study skills and learning habits

5. ***Reasoning:*** *Discovers a rule or principle underlying the relationship between two or more objects and applies it when solving a problem*
    a. Demonstrates use of simple logic
    b. Demonstrates ability to distinguish relationships
    c. Demonstrates ability to determine and isolate factors in relationships
    d. Demonstrates and applies knowledge through practice
    e. Recognizes that attitudes, skills, and practice are essential to productivity
    f. Demonstrates ability to discriminate between positive and negative, and act accordingly

C. **Personal Qualities:** Displays responsibility, self-esteem, sociability, self-management, and integrity and honesty
  1. ***Responsibility:*** *Exerts a high level of effort and perseveres towards goal attainment*
      a. Demonstrates ability to formulate realistic and useful short and long term goals and complete steps necessary to timely achieve goals
      b. Demonstrates ability to make adjustments, revisions, and changes to achieve goals in a cooperative and polite manner
      c. Demonstrates ability to focus on task at hand and work to completion
      d. Demonstrates good work ethics through regular attendance, adequate classroom preparations, and appropriate use of classroom time
      e. Demonstrates maturity to take responsibility for actions
      f. Demonstrates ability to cooperatively work in individual, team, and group situations in timely and effective manner
  2. ***Self-Esteem:*** *Believes in own self-worth and maintains a positive view of self*
      a. Presents a positive attitude toward tasks
      b. Demonstrates ability to separate work and personal behaviors
      c. Actively participates in learning opportunities by sharing knowledge and skills with peers and instructors
      d. Demonstrates ability to accept personal strengths and weaknesses and builds on positive behaviors
      e. Demonstrates ability to accept and use constructive criticism
      f. Accepts positive reinforcement in an appropriate manner

3. ***Sociability:** Demonstrates understanding, friendliness, adaptability, empathy, and politeness in group settings*
    a. Demonstrates appropriate and acceptable social behaviors in interactions
    b. Demonstrates ability to work cooperatively in individual, team, or group situations
    c. Demonstrates active interest in peers by offering assistance, sharing resources, and sharing knowledge in a professional and acceptable manner
    d. Demonstrates professional work ethic by separating work and personal social behaviors and acting accordingly
4. ***Self-Management:** Assesses self accurately, sets personal goals, monitors progress, and exhibits self-control*
    a. Accepts personal strengths and weaknesses and uses the same for positive advancement
    b. Demonstrates ability to continuously set, assess, choose, and modify objectives as the situation demands in an appropriate manner
    c. Demonstrates ability to formulate and follow personal schedules
    d. Demonstrates ability to wisely use classroom time
    e. Demonstrates use of good study habits and skills
    f. Demonstrates maturity to take responsibility for own actions
5. ***Integrity/Honesty:** Chooses ethical courses of action*
    a. Knows and demonstrates ability to distinguish between positive and negative behaviors
    b. Demonstrates honesty and integrity in working with peers and supervisors
    c. Takes full responsibility for personal actions
    d. Demonstrates understanding of consequences for negative ethical behaviors and accepts responsibility for same when applicable
    e. Demonstrates positive work and social ethics in undertakings

Appropriate Reference Materials:

1. MASTER Technical Modules:
    CNC-A1 through CNC-A5;
    CNC-B1 through CNC-B8;
    CNC-C1 through CNC-C10;
    CNC-E1 through CNC-E6;
    CNC-G1 through CNC-G4; and,

CNC-H1 through CNC-H5.

2. *Anilam Vertical Machining Program Manual,* Latest Edition
3. *Fadal Programming Manual,* Latest Edition
4. *Bridgeport Programming Manual,* Latest Edition
5. *Greco Systems Manual,* Latest Edition
6. *Hansvedt Operating Manual,* Latest Edition

CNC 171
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CNC 180

MASTER PROGRAM

Advanced CAD/CAM

COURSE SYLLABUS

Total lecture hours: 48 **Total lab hours: 48** **Credit hours: 4**

COURSE DESCRIPTION:

Advanced CAD/CAM theory and software. The emphasis will be on the generation of CNC programs, using advanced modeling techniques for both CNC Mill and CNC Lathe.

PREREQUISITES: **Introduction to CAD/CAM**

COURSE OBJECTIVES:

After successful completion of this course, the students will be able to:

1. Use verification software to analyze the effects of speeds, feeds and depth of cut and total volume of material removal;
2. Demonstrate the correct use of CAD/CAM software to create 2 and 3 basic dimensional geometric shapes and surface models;
3. Demonstrate the ability to modify post–processor and co–processor data files;
4. Properly identify various parts of CNC program generation;
5. Perform editing of CNC programs using various software;
6. Demonstrate use of communications module within CAD/CAM software;
7. Demonstrate an understanding of the use of multiple tool planes and multi–axis machining;
8. Demonstrate proper use of personal computers for routine maintenance of systems;
9. Demonstrate a basic understanding of the common DOS and Windows commands as used on personal computers;
10. Demonstrate reading and writing skills to read and prepare required documents for course work; and,
11. Demonstrate communication skills to interact successfully with members of working teams and instructor.

REQUIRED COURSE MATERIALS:

Textbooks: *MasterCam For Windows*, Latest Edition
Lab Manual: None

Supplies:
Computer Diskettes

METHOD OF INSTRUCTION:

Lecture:	Presentations will include lecture, with or without various audio–visual aids; discussion, debate, and/or critique; demonstration; computer–assisted or other self–paced instruction; field trips or field assignments.
Laboratory:	Laboratory will be a hands–on process.

Method of Evaluation: A student's grade will be based on multiple measures of performance. The assessment will measure development of independent critical thinking skills and will include evaluation of the student's ability to:

1. Perform the manipulative skills of the craft as required to satisfactorily complete laboratory assignments;
2. Apply theory to laboratory assignments;
3. Satisfactorily perform on written, oral, or practical examinations;
4. Satisfactorily perform on outside assignments including writing assignments;
5. Contribute to class discussions;
6. Maintain attendance per current policy; and,
7. Follow all laboratory rules and safety regulations.

LECTURE OUTLINE:

Lecture Topics	Contact Hrs.
Basic Geometry Generation Review	
A. Contours	
B. Pockets	
C. Lettering	
D. Drilling	
Basic Tool Paths Generation Review	
A. Contours	
B. Pockets	
C. Lettering	
D. Drilling	
Advanced Geometries	
A. Ruled surfaces	
B. Coons surface	
C. Lofted surfaces	
D. 3–D Swept surfaces	
Tooling Parameters	
A. Definition of materials	

B. Definition of tool files
C. Discussion of speeds, and feeds
D. Discussion of cutting tools and geometries

Intermediate Files
A. Backplotting completed intermediate files
B. Editing intermediate files
C. Merging intermediate files
D. Projection of intermediate files

Generating CNC Code
A. Selection of post, or co–processors
B. Operation of post, or co–processors
C. Reverse postprocessing
D. Edit processors

Communication Parameters
A. RS–232 interface
B. Downloading
C. Uploading
D. Handshaking
E. Greco System's communication

Personal Computer Systems Requirements
A. Basic terminology
B. Basic operation
C. Basic DOS commands

Total Lecture Hours **48**

LAB OUTLINE:

Lab Topics	Contact Hrs.
Basic Geometry Generation Review	
Basic Tool Paths Generation Review	
Advanced Geometries	
Tooling Parameters	
Intermediate Files	
Generating CNC Code	
Communication parameters	
Personal Computer Systems Requirements	
Total Lab Hours	**48**

COURSE OBJECTIVES: SCANS COMPETENCIES

The Secretary's Commission on Achieving Necessary Skills (SCANS), U.S. Department of Labor, has identified in its "AMERICA 2000 REPORT" that all students should develop a new set of competencies and foundation skills if they are to enjoy a productive, *full and satisfying life. These are in addition to the Technical Workplace Competencies required by industry. SCANS is made up of five competencies and a three-part foundation of skills and personal qualities that are needed for solid job performance. All italicized headings in this section are direct quotations from "What Work Requires of Schools: A SCANS Report for America 2000."*

The following activities will be performed by each student for successful completion of this course:

I. COMPETENCIES
  A. *Resources: Identifies, organizes, plans, and allocates resources*
    1. Allocates time to complete assigned tasks on schedule
    2. Determines and allocates required materials and resources for meeting objectives
    3. Evaluates skills, performance, and quality of work and provides feedback
  B. *Interpersonal: Works with others*
    1. Participates as a member of the team, contributing to group effort
    2. Provides individual assistance/direction to peers as requested
    3. Determines and meets expectations
    4. Exercises leadership qualities to effectively communicate ideas and make decisions.
    5. Negotiates resources in order to accomplish objectives
    6. Works well with all members of the class
  C. *Information: Acquires and uses information*
    1. Acquires and evaluates information
    2. Organizes and maintains information
    3. Interprets and communicates information
  D. *Systems: Understands complex inter-relationships*
    1. Understands and works well with social, organizational, and technological systems
    2. Monitors and corrects performance of system during operation
    3. Recommends modifications to system to improve performance
  E. *Technology: Works with a variety of technologies*
    1. Chooses relevant procedures, tools, and equipment
    2. Applies appropriate procedures and techniques to accomplish tasks
    3. Identifies or solves problems to maintain equipment

II. FOUNDATION SKILLS
  A. **Basic Skills:** Reads, writes, performs arithmetic and mathematical operations, listens and speaks

1. ***Reading:*** *Locates, understands, and interprets written information in prose and in documents such as manuals, graphs, and schedules*
    a. **Demonstrates basic reading skills including abilities to perceive main ideas, draw appropriate conclusions, detect a sequence, locate answers, find facts, and infer from written texts**
    b. **Demonstrates course specific reading skills including abilities to read, interpret, and comprehend information from text and supplemental materials on a level to facilitate productive independent and group study**
    c. **Demonstrates ability to read, interpret, and utilize information from course specific instruments (i.e., charts, diagrams, graphs, schematics, blueprints, flow charts, etc.)**
    d. **Demonstrates ability to read, interpret, and follow schedules and procedural instructions in a timely and appropriate manner**
    e. **Demonstrates ability to choose and use most appropriate reading method (skim, scan, or read for comprehension) for materials**
2. ***Writing:*** *Communicates thoughts, ideas, information, and messages in writing; and creates documents such as letters, directions, manuals, reports, graphs, and flow charts*
    a. **Demonstrates basic writing skills including abilities to produce written documents which conform with accepted grammatical and communication standards required for effective daily functioning**
    b. **Demonstrates effective written study skills including note taking, maintaining course specific journals, workbooks, manuals, etc.**
    c. **Demonstrates technical writing skills in preparing outlines, summaries, time lines, flow charts, diagrams, etc. appropriate to materials covered**
    d. **Demonstrates ability to complete all required writings in a timely, complete, and professional manner**
    e. **Demonstrates competence in subject matter through the organization and presentation of answers to required written assessments**
3. ***Arithmetic/Mathematics:*** *Perform basic computations and approaches practical problems by choosing appropriately from a variety of mathematical techniques*

   - a. Demonstrates proficiency in basic arithmetic functions including ability to add, subtract, multiply, and divide whole numbers, fractions, decimals, and percentages
   - b. Demonstrates ability to read, comprehend, and select appropriate math procedures to work basic math problems
   - c. Demonstrates ability to understand and perform multi-step computations
   - d. Demonstrates ability to read, interpret, and use standard measuring devices
   - e. Demonstrates ability to comprehend, retain, and utilize course specific measuring devices effectively
   - f. Demonstrates ability to understand, retain, and utilize higher mathematical formulas and functions required for course specific math performance
   - g. Demonstrates ability to appropriately transfer mathematical calculations and information from paper to machines

4. ***Listening:*** *Receives, attends to, interprets, and responds to verbal messages and other cues*
   - a. Functions at minimal or above required hearing levels to receive, attend, interpret, and respond to verbal messages and instructions and to safely operate machinery
   - b. Demonstrates ability to hear, comprehend, and appropriately follow directions
   - c. Demonstrates auditory ability to hear, comprehend, and utilize verbal classroom as well as other auditory instruction
   - d. Demonstrates ability to discriminate between essential and non-essential verbal information and react appropriately
   - e. Demonstrates ability to focus and fine-tune listening skills to receive, interpret, and respond to various sounds
   - f. Demonstrates ability and maturity to seek and receive additional individualized instruction as needed
5. ***Speaking***: *Organizes ideas and communicates orally*
   - a. Demonstrates appropriate listening and speaking skills in personal conversations
   - b. Demonstrates ability to choose and organize appropriate words to effectively communicate
   - c. Demonstrates ability to speak clearly and distinctly with appropriate volume, tone, and body language for situation

        d. Demonstrates ability to spontaneously organize and present appropriate answers and/or short presentations for classroom and /or assessment purposes
        e. Demonstrates ability to formulate, organize, and deliver major presentations to peers or groups
        f. Demonstrates ability to speak effectively in one-on-one, small group, or large group presentations
        g. Demonstrates ability to take responsibility for presentations

B. **Thinking Skills:** Thinks creatively, makes decisions, solves problems, visualizes, knows how to learn and reasons
    1. ***Decision Making:*** *Specifies goals and constraints, generates alternatives, considers risks, and evaluates and chooses best alternative*
        a. Demonstrates ability to objectively assess personal strengths and weaknesses
        b. Demonstrates ability to set realistic short-term and long-term goals
        c. Demonstrates ability to recognize and distinguish between positive and negative alternatives
        d. Demonstrates ability to identify potential pitfalls and take evasive actions
        e. Demonstrates ability to objectively and responsibly evaluate alternatives by testing hypotheses and selecting most appropriate response
        f. Demonstrates ability to profit from negative evaluations or mistakes by reformulating, redirecting, reconstructing, or retesting alternatives
        g. Demonstrates maturity in taking responsibility for decisions
    2. ***Problem Solving:*** *Recognizes problems and devises and implements plan of action*
        a. Demonstrates ability to detect problem through observation, inquiry, or directive
        b. Demonstrates ability to grasp appropriate overview and degree of seriousness of problem and to behave responsibly in situation
        c. Demonstrates ability to generate alternatives or options for problem solution
        d. Demonstrates ability to research options, assess and evaluate options, and determine appropriate and best solution
        e. Demonstrates ability to initiate and effect solution
        f. Demonstrates ability to take responsibility for outcomes

g. Demonstrates ability to effectively problem solve in individual, team, or group situations

3. ***Seeing Things In the Mind's Eye:*** *Organizes, and processes symbols, pictures, graphs, objects, and other information*
    - a. Functions at minimum or above required visual levels in order to see, interpret, attend and respond to visual imagery and meet safety requirements for necessary machinery
    - b. Demonstrates ability to read, interpret, and act upon signs, symbols, and other visual cues
    - c. Demonstrates ability to visually discriminate in gross and fine imagery
    - d. Demonstrates ability to visualize abstractly
    - e. Demonstrates ability to apply visual imagery to applied tasks
4. ***Knowing How to Learn:*** *Use efficient learning techniques to acquire and apply new knowledge and skills*
    - a. Demonstrates mastery of basic reading, math, and language skills through application
    - b. Demonstrates ability to translate abstract theory into practical application
    - c. Demonstrates ability to incorporate and generalize new learning into a sequential learning process
    - d. Demonstrates knowledge of good study skills and learning habits
5. ***Reasoning:*** *Discovers a rule or principle underlying the relationship between two or more objects and applies it when solving a problem*
    - a. Demonstrates use of simple logic
    - b. Demonstrates ability to distinguish relationships
    - c. Demonstrates ability to determine and isolate factors in relationships
    - d. Demonstrates and applies knowledge through practice
    - e. Recognizes that attitudes, skills, and practice are essential to productivity
    - f. Demonstrates ability to discriminate between positive and negative, and act accordingly

C. **Personal Qualities:** Displays responsibility, self-esteem, sociability, self-management, and integrity and honesty

1. ***Responsibility:*** *Exerts a high level of effort and perseveres towards goal attainment*
    - a. Demonstrates ability to formulate realistic and useful short and long term goals and complete steps necessary to timely achieve goals

   - b. Demonstrates ability to make adjustments, revisions, and changes to achieve goals in a cooperative and polite manner
   - c. Demonstrates ability to focus on task at hand and work to completion
   - d. Demonstrates good work ethics through regular attendance, adequate classroom preparations, and appropriate use of classroom time
   - e. Demonstrates maturity to take responsibility for actions
   - f. Demonstrates ability to cooperatively work in individual, team, and group situations in timely and effective manner

2. ***Self-Esteem:*** *Believes in own self-worth and maintains a positive view of self*
   - a. Presents a positive attitude toward tasks
   - b. Demonstrates ability to separate work and personal behaviors
   - c. Actively participates in learning opportunities by sharing knowledge and skills with peers and instructors
   - d. Demonstrates ability to accept personal strengths and weaknesses and builds on positive behaviors
   - e. Demonstrates ability to accept and use constructive criticism
   - f. Accepts positive reinforcement in an appropriate manner

3. ***Sociability:*** *Demonstrates understanding, friendliness, adaptability, empathy, and politeness in group settings*
   - a. Demonstrates appropriate and acceptable social behaviors in interactions
   - b. Demonstrates ability to work cooperatively in individual, team, or group situations
   - c. Demonstrates active interest in peers by offering assistance, sharing resources, and sharing knowledge in a professional and acceptable manner
   - d. Demonstrates professional work ethic by separating work and personal social behaviors and acting accordingly

4. ***Self-Management:*** *Assesses self accurately, sets personal goals, monitors progress, and exhibits self-control*
   - a. Accepts personal strengths and weaknesses and uses the same for positive advancement
   - b. Demonstrates ability to continuously set, assess, choose, and modify objectives as the situation demands in an appropriate manner
   - c. Demonstrates ability to formulate and follow personal schedules

    d. Demonstrates ability to wisely use classroom time
    e. Demonstrates use of good study habits and skills
    f. Demonstrates maturity to take responsibility for own actions

5. *Integrity/Honesty: Chooses ethical courses of action*
    a. Knows and demonstrates ability to distinguish between positive and negative behaviors
    b. Demonstrates honesty and integrity in working with peers and supervisors
    c. Takes full responsibility for personal actions
    d. Demonstrates understanding of consequences for negative ethical behaviors and accepts responsibility for same when applicable
    e. Demonstrates positive work and social ethics in undertakings

Appropriate Reference Materials:

1. MASTER Technical Modules:
    CNC-B1 through CNC-B8;
    CNC-C1 through CNC-C10;
    CNC-E1 through CNC-E6;
    CNC-G2 through CNC-G4;
    CNC-H1 through CNC-H5; and,
    CNC-I1 through CNC-I5.
2. *SmartCam Programming Manuals,* Latest Edition
3. *Anilam Vertical Machining Program Manual,* Latest Edition
4. *Bendix Dynapath Manual,* Latest Edition
5. *Fadal Programming Manual,* Latest Edition
6. *Fanuc 6T Programming Manual,* Latest Edition
7. *Greco System Manual,* Latest Edition
8. *Vericut Programming Manual,* Latest Edition
9. *N–See Programming Manual,* Latest Edition
10. *SurfCam Programming Manual,* Latest Edition

CNC 180
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CNC 181

MASTER PROGRAM

Application in Advanced CAD/CAM I

COURSE SYLLABUS

Total lecture hours: 0 **Total lab hours: 96** **Credit hours: 2**

COURSE DESCRIPTION:

Exercises in CAD/CAM theory and software at an intermediate level. The emphasis will be on the generation of CNC programs, at an intermediate level, for both CNC Mill, and CNC Lathe. This class is designed to allow the student the opportunity to improve efficiency in the application of immediate CAD/CAM.

PREREQUISITES: **Advanced CAD/CAM or concurrent enrollment**

COURSE OBJECTIVES:

After successful completion of this course, the students will be able to:

1. Use verification software to analyze the effects of speeds, feeds and depth of cut and total volume of material removed with an intermediate Ievel of quality and quantity of projects;
2. Demonstrate use of CAD/CAM software to create 2 and 3 dimensional geometric shapes and surface models on multiple level drawings and with required tool paths at an intermediate level of quality and quantity of projects;
3. Modify previously constructed 3 dimensional surface models;
4. Demonstrate the ability to modify post-processor and co–processor data files;
5. Perform editing of surface models;
6. Demonstrate proper use of utility packages in conjunction with CAM packages;
7. Demonstrate the basic use of multiple tool planes and multi–axis machining;
8. Demonstrate proper use of personal computers for routine maintenance of systems;
9. Complete assigned projects using required skills with limited hands–on instruction by the instructor;
10. Demonstrate a understanding of the DOS and Windows commands as used on personal computers at an intermediate level of quality and quantity of projects;
11. Demonstrate reading and writing skills to read and prepare required documents for course work; and,

12. Demonstrate communication skills to interact successfully with members of working teams and instructor.

REQUIRED COURSE MATERIALS:

Textbooks: *MasterCam For Windows,* Latest Edition
Lab Manual: None

Supplies:
Computer diskettes

METHOD OF INSTRUCTION:

Lecture: Presentations will include lecture, with or without various audio–visual aids; discussion, debate, and/or critique; demonstration; computer–assisted or other self–paced instruction; field trips or field assignments.

Laboratory: Laboratory will be a hands–on process.

Method of Evaluation: A student's grade will be based on multiple measures of performance. The assessment will measure development of independent critical thinking skills and will include evaluation of the student's ability to:

1. Perform the manipulative skills of the craft as required to satisfactorily complete laboratory assignments;
2. Apply theory to laboratory assignments;
3. Satisfactorily perform on written, oral, or practical examinations;
4. Satisfactorily perform on outside assignments including writing assignments;
5. Contribute to class discussions;
6. Maintain attendance per current policy; and,
7. Follow all laboratory rules and safety regulations.

LAB OUTLINE:

Lab Topics	Contact Hrs.
Geometry Generation Review	
A. Contours	
B. Pockets	
C. Lettering	
D. Drilling	
Tool Paths Generation Review	
A. Contours	
B. Pockets	
C. Lettering	

D. Drilling

Advanced Geometries

A. Ruled surfaces projection
B. Coons surface projection
C. Lofted surfaces projection
D. 3–D Swept surfaces

Intermediate Files

A. Back plotting completed intermediate files for surfaces
B. Editing intermediate files for surfaces
C. Merging intermediate files for surfaces
D. Projection of intermediate files onto surfaces

Generating CNC Code Review

A. Selection of post, or co–processors
B. Operation of post, or co–processors
C. Reverse postprocessing
D. Edit processors

Communication Parameters

A. Using CAM software to facilitate RS–232 interface
B. Using CAM software to facilitate downloading of programs
C. Using CAM software to facilitate uploading of programs
D. Using CAM software to facilitate handshaking of machine centers with computers

Total Lab Hours **96**

COURSE OBJECTIVES: SCANS COMPETENCIES

The Secretary's Commission on Achieving Necessary Skills (SCANS), U.S. Department of Labor, has identified in its "AMERICA 2000 REPORT" that all students should develop a new set of competencies and foundation skills if they are to enjoy a productive, full and satisfying life. These are in addition to the Technical Workplace Competencies required by industry. SCANS is made up of five competencies and a three-part foundation of skills and personal qualities that are needed for solid job performance. All italicized headings in this section are direct quotations from "What Work Requires of Schools: A SCANS Report for America 2000."

The following activities will be performed by each student for successful completion of this course:

I. COMPETENCIES
   *A. **Resources:** Identifies, organizes, plans, and allocates resources*

    1. Allocates time to complete assigned tasks on schedule
    2. Determines and allocates required materials and resources for meeting objectives
    3. Evaluates skills, performance, and quality of work and provides feedback
  - *B.* ***Interpersonal:*** *Works with others*
    1. Participates as a member of the team, contributing to group effort
    2. Provides individual assistance/direction to peers as requested
    3. Determines and meets expectations
    4. Exercises leadership qualities to effectively communicate ideas and make decisions.
    5. Negotiates resources in order to accomplish objectives
    6. Works well with all members of the class
  - *C.* ***Information:*** *Acquires and uses information*
    1. Acquires and evaluates information
    2. Organizes and maintains information
    3. Interprets and communicates information
  - *D.* ***Systems:*** *Understands complex inter-relationships*
    1. Understands and works well with social, organizational, and technological systems
    2. Monitors and corrects performance of system during operation
    3. Recommends modifications to system to improve performance
  - *E.* ***Technology:*** *Works with a variety of technologies*
    1. Chooses relevant procedures, tools, and equipment
    2. Applies appropriate procedures and techniques to accomplish tasks
    3. Identifies or solves problems to maintain equipment

- II. FOUNDATION SKILLS
  - A. **Basic Skills:** Reads, writes, performs arithmetic and mathematical operations, listens and speaks
    - *1.* ***Reading:*** *Locates, understands, and interprets written information in prose and in documents such as manuals, graphs, and schedules*
      - a. Demonstrates basic reading skills including abilities to perceive main ideas, draw appropriate conclusions, detect a sequence, locate answers, find facts, and infer from written texts
      - b. Demonstrates course specific reading skills including abilities to read, interpret, and comprehend information from text and supplemental materials on a level to facilitate productive independent and group study

- c. Demonstrates ability to read, interpret, and utilize information from course specific instruments (i.e., charts, diagrams, graphs, schematics, blueprints, flow charts, etc.)
- d. Demonstrates ability to read, interpret, and follow schedules and procedural instructions in a timely and appropriate manner
- e. Demonstrates ability to choose and use most appropriate reading method (skim, scan, or read for comprehension) for materials

2. ***Writing:** Communicates thoughts, ideas, information, and messages in writing; and creates documents such as letters, directions, manuals, reports, graphs, and flow charts*
    - a. Demonstrates basic writing skills including abilities to produce written documents which conform with accepted grammatical and communication standards required for effective daily functioning
    - b. Demonstrates effective written study skills including note taking, maintaining course specific journals, workbooks, manuals, etc.
    - c. Demonstrates technical writing skills in preparing outlines, summaries, time lines, flow charts, diagrams, etc. appropriate to materials covered
    - d. Demonstrates ability to complete all required writings in a timely, complete, and professional manner
    - e. Demonstrates competence in subject matter through the organization and presentation of answers to required written assessments
3. ***Arithmetic/Mathematics:** Perform basic computations and approaches practical problems by choosing appropriately from a variety of mathematical techniques*
    - a. Demonstrates proficiency in basic arithmetic functions including ability to add, subtract, multiply, and divide whole numbers, fractions, decimals, and percentages
    - b. Demonstrates ability to read, comprehend, and select appropriate math procedures to work basic math problems
    - c. Demonstrates ability to understand and perform multi-step computations
    - d. Demonstrates ability to read, interpret, and use standard measuring devices
    - e. Demonstrates ability to comprehend, retain, and utilize course specific measuring devices effectively

- f. Demonstrates ability to understand, retain, and utilize higher mathematical formulas and functions required for course specific math performance
- g. Demonstrates ability to appropriately transfer mathematical calculations and information from paper to machines

4. ***Listening:*** *Receives, attends to, interprets, and responds to verbal messages and other cues*
    - a. Functions at minimal or above required hearing levels to . receive, attend, interpret, and respond to verbal messages and instructions and to safely operate machinery
    - b. Demonstrates ability to hear, comprehend, and appropriately follow directions
    - c. Demonstrates auditory ability to hear, comprehend, and utilize verbal classroom as well as other auditory instruction
    - d. Demonstrates ability to discriminate between essential and non-essential verbal information and react appropriately
    - e. Demonstrates ability to focus and fine-tune listening skills to receive, interpret, and respond to various sounds
    - f. Demonstrates ability and maturity to seek and receive additional individualized instruction as needed
5. ***Speaking*:** *Organizes ideas and communicates orally*
    - a. Demonstrates appropriate listening and speaking skills in personal conversations
    - b. Demonstrates ability to choose and organize appropriate words to effectively communicate
    - c. Demonstrates ability to speak clearly and distinctly with appropriate volume, tone, and body language for situation
    - d. Demonstrates ability to spontaneously organize and present appropriate answers and/or short presentations for classroom and /or assessment purposes
    - e. Demonstrates ability to formulate, organize, and deliver major presentations to peers or groups
    - f. Demonstrates ability to speak effectively in one-on-one, small group, or large group presentations
    - g. Demonstrates ability to take responsibility for presentations

B. **Thinking Skills:** Thinks creatively, makes decisions, solves problems, visualizes, knows how to learn and reasons

1. ***Decision Making:*** *Specifies goals and constraints, generates alternatives, considers risks, and evaluates and chooses best alternative*

- a. Demonstrates ability to objectively assess personal strengths and weaknesses
- b. Demonstrates ability to set realistic short-term and long-term goals
- c. Demonstrates ability to recognize and distinguish between positive and negative alternatives
- d. Demonstrates ability to identify potential pitfalls and take evasive actions
- e. Demonstrates ability to objectively and responsibly evaluate alternatives by testing hypotheses and selecting most appropriate response
- f. Demonstrates ability to profit from negative evaluations or mistakes by reformulating, redirecting, reconstructing, or retesting alternatives
- g. Demonstrates maturity in taking responsibility for decisions

2. ***Problem Solving:** Recognizes problems and devises and implements plan of action*
   - a. Demonstrates ability to detect problem through observation, inquiry, or directive
   - b. Demonstrates ability to grasp appropriate overview and degree of seriousness of problem and to behave responsibly in situation
   - c. Demonstrates ability to generate alternatives or options for problem solution
   - d. Demonstrates ability to research options, assess and evaluate options, and determine appropriate and best solution
   - e. Demonstrates ability to initiate and effect solution
   - f. Demonstrates ability to take responsibility for outcomes
   - g. Demonstrates ability to effectively problem solve in individual, team, or group situations
3. ***Seeing Things In the Mind's Eye:** Organizes, and processes symbols, pictures, graphs, objects, and other information*
   - a. Functions at minimum or above required visual levels in order to see, interpret, attend and respond to visual imagery and meet safety requirements for necessary machinery
   - b. Demonstrates ability to read, interpret, and act upon signs, symbols, and other visual cues
   - c. Demonstrates ability to visually discriminate in gross and fine imagery
   - d. Demonstrates ability to visualize abstractly

      e. Demonstrates ability to apply visual imagery to applied tasks
   4. ***Knowing How to Learn:** Use efficient learning techniques to acquire and apply new knowledge and skills*
      a. Demonstrates mastery of basic reading, math, and language skills through application
      b. Demonstrates ability to translate abstract theory into practical application
      c. Demonstrates ability to incorporate and generalize new learning into a sequential learning process
      d. Demonstrates knowledge of good study skills and learning habits
   5. ***Reasoning:** Discovers a rule or principle underlying the relationship between two or more objects and applies it when solving a problem*
      a. Demonstrates use of simple logic
      b. Demonstrates ability to distinguish relationships
      c. Demonstrates ability to determine and isolate factors in relationships
      d. Demonstrates and applies knowledge through practice
      e. Recognizes that attitudes, skills, and practice are essential to productivity
      f. Demonstrates ability to discriminate between positive and negative, and act accordingly

C. **Personal Qualities:** Displays responsibility, self-esteem, sociability, self-management, and integrity and honesty
   1. ***Responsibility:** Exerts a high level of effort and perseveres towards goal attainment*
      a. Demonstrates ability to formulate realistic and useful short and long term goals and complete steps necessary to timely achieve goals
      b. Demonstrates ability to make adjustments, revisions, and changes to achieve goals in a cooperative and polite manner
      c. Demonstrates ability to focus on task at hand and work to completion
      d. Demonstrates good work ethics through regular attendance, adequate classroom preparations, and appropriate use of classroom time
      e. Demonstrates maturity to take responsibility for actions
      f. Demonstrates ability to cooperatively work in individual, team, and group situations in timely and effective manner

2. *Self-Esteem: Believes in own self-worth and maintains a positive view of self*
    a. Presents a positive attitude toward tasks
    b. Demonstrates ability to separate work and personal behaviors
    c. Actively participates in learning opportunities by sharing knowledge and skills with peers and instructors
    d. Demonstrates ability to accept personal strengths and weaknesses and builds on positive behaviors
    e. Demonstrates ability to accept and use constructive criticism
    f. Accepts positive reinforcement in an appropriate manner
3. *Sociability: Demonstrates understanding, friendliness, adaptability, empathy, and politeness in group settings*
    a. Demonstrates appropriate and acceptable social behaviors in interactions
    b. Demonstrates ability to work cooperatively in individual, team, or group situations
    c. Demonstrates active interest in peers by offering assistance, sharing resources, and sharing knowledge in a professional and acceptable manner
    d. Demonstrates professional work ethic by separating work and personal social behaviors and acting accordingly
4. *Self-Management: Assesses self accurately, sets personal goals, monitors progress, and exhibits self-control*
    a. Accepts personal strengths and weaknesses and uses the same for positive advancement
    b. Demonstrates ability to continuously set, assess, choose, and modify objectives as the situation demands in an appropriate manner
    c. Demonstrates ability to formulate and follow personal schedules
    d. Demonstrates ability to wisely use classroom time
    e. Demonstrates use of good study habits and skills
    f. Demonstrates maturity to take responsibility for own actions
5. *Integrity/Honesty: Chooses ethical courses of action*
    a. Knows and demonstrates ability to distinguish between positive and negative behaviors
    b. Demonstrates honesty and integrity in working with peers and supervisors
    c. Takes full responsibility for personal actions

d. **Demonstrates understanding of consequences for negative ethical behaviors and accepts responsibility for same when applicable**

e. **Demonstrates positive work and social ethics in undertakings**

Appropriate Reference Materials:

1. MASTER Technical Modules:
    CNC-B1 through CNC-B8;
    CNC-C1 through CNC-C10;
    CNC-E1 through CNC-E6;
    CNC-G2 through CNC-G4;
    CNC-H1 through CNC-H5; and,
    CNC-I1 through CNC-I5.
2. *SmartCam Programming Manuals,* **Latest Edition**
3. *Anilam Vertical Machining Program Manual,* **Latest Edition**
4. *Bendix Dynapath Manual,* **Latest Edition**
5. *Fadal Programming Manual,* **Latest Edition**
6. *Fanuc 6T Programming Manual,* **Latest Edition**
7. *Greco System Manual,* **Latest Edition**
8. *Vericut Programming Manual,* **Latest Edition**
9. *N-See Programming Manual,* **Latest Edition**
10. *SurfCam Programming Manual,* **Latest Edition**

CNC 181
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CNC 190

MASTER PROGRAM

Introduction to CNC Controlled Turning

COURSE SYLLABUS

Total lecture hours: 48 **Total lab hours:** 48 **Credit hours:** 4

COURSE DESCRIPTION:

Theory of CNC Turning techniques. Emphasis placed on basic operations of CNC Turning. Students in this class are expected to have previous machining experience.

PREREQUISITES: **Introduction to CNC and EDM**

COURSE OBJECTIVES:

After successful completion of this course, the students will be able to:

1. Use verification software to analyze the effects of speeds, feeds, and depth of cut and total volume of material removed;
2. Identify CNC Lathes and their controls and accessories;
3. Use charts, reference tables, math calculations to determine speeds and feeds;
4. Demonstrate the proper set up procedures for the Webb–Ecostar, ANSAM Lathemate, and Bendix CNC lathes;
5. Demonstrate proper use of controller to set offsets, edit programs, and create programs at the controller;
6. Demonstrate a basic understanding of the common "G" and "M" codes as used on CNC machines to create various programs;
7. Complete assigned projects using required skills with hands-on instruction by the instructor;
8. Demonstrate reading and writing skills to read and prepare required documents for course work; and,
9. Demonstrate communication skills to interact successfully with members of working teams and instructor.

REQUIRED COURSE MATERIALS:

Textbooks: *Technology of Machine Tools,* Latest Edition, or
Fundamentals of Numerical Control, Latest Edition, or
Computer Numerical Control: From Programming to Networking, Latest Edition, or

Lab Manual: None

Supplies:

Computer Diskettes

METHOD OF INSTRUCTION

Lecture: Presentations will include lecture, with or without various audio–visual aids; discussion, debate, and/or critique; demonstration; computer–assisted or other self–paced instruction; field trips or field assignments.

Laboratory: Laboratory will be a hands–on process utilizing specifically planned instructional activities or "live" work..

Method of Evaluation: A student's grade will be based on multiple measures of performance. The assessment will measure development of independent critical thinking skills and will include evaluation of the student's ability to:

1. Perform the manipulative skills of the craft as required to satisfactorily complete laboratory assignments;
2. Apply theory to laboratory assignments;
3. Satisfactorily perform on written, oral, or practical examinations;
4. Satisfactorily perform on outside assignments including writing assignments;
5. Contribute to class discussions;
6. Maintain attendance per current policy; and,
7. Follow all laboratory rules and safety regulations.

LECTURE OUTLINE:

Lecture Topics	Contact Hrs.
Total Lecture Hours	48

LAB OUTLINE:

Lab Topics	Contact Hrs.
Total Lab Hours	48

COURSE OBJECTIVES: SCANS COMPETENCIES

The Secretary's Commission on Achieving Necessary Skills (SCANS), U.S. Department of Labor, has identified in its "AMERICA 2000 REPORT" that all students should *develop a new set of competencies and foundation skills if they are to enjoy a productive, full and satisfying life. These are in addition to the Technical Workplace Competencies required by industry. SCANS is made up of five competencies and a three-part foundation of skills and personal qualities that are needed for solid job performance. All italicized headings in this section are direct quotations from "What Work Requires of Schools: A SCANS Report for America 2000."*

The following activities will be performed by each student for successful completion of this course:

I. COMPETENCIES

A. *Resources: Identifies, organizes, plans, and allocates resources*
   1. Allocates time to complete assigned tasks on schedule
   2. Determines and allocates required materials and resources for meeting objectives
   3. Evaluates skills, performance, and quality of work and provides feedback

B. *Interpersonal: Works with others*
   1. Participates as a member of the team, contributing to group effort
   2. Provides individual assistance/direction to peers as requested
   3. Determines and meets expectations
   4. Exercises leadership qualities to effectively communicate ideas and make decisions.
   5. Negotiates resources in order to accomplish objectives
   6. Works well with all members of the class

C. *Information: Acquires and uses information*
   1. Acquires and evaluates information
   2. Organizes and maintains information
   3. Interprets and communicates information

D. *Systems: Understands complex inter-relationships*
   1. Understands and works well with social, organizational, and technological systems
   2. Monitors and corrects performance of system during operation
   3. Recommends modifications to system to improve performance

E. *Technology: Works with a variety of technologies*
   1. Chooses relevant procedures, tools, and equipment
   2. Applies appropriate procedures and techniques to accomplish tasks
   3. Identifies or solves problems to maintain equipment

II. FOUNDATION SKILLS

A. **Basic Skills:** Reads, writes, performs arithmetic and mathematical operations, listens and speaks

   1. ***Reading:*** *Locates, understands, and interprets written information in prose and in documents such as manuals, graphs, and schedules*
      - a. Demonstrates basic reading skills including abilities to perceive main ideas, draw appropriate conclusions, detect a sequence, locate answers, find facts, and infer from written texts
      - b. Demonstrates course specific reading skills including abilities to read, interpret, and comprehend information from text and supplemental materials on a level to facilitate productive independent and group study
      - c. Demonstrates ability to read, interpret, and utilize information from course specific instruments (i.e., charts, diagrams, graphs, schematics, blueprints, flow charts, etc.)
      - d. Demonstrates ability to read, interpret, and follow schedules and procedural instructions in a timely and appropriate manner
      - e. Demonstrates ability to choose and use most appropriate reading method (skim, scan, or read for comprehension) for materials
   2. ***Writing:*** *Communicates thoughts, ideas, information, and messages in writing; and creates documents such as letters, directions, manuals, reports, graphs, and flow charts*
      - a. Demonstrates basic writing skills including abilities to produce written documents which conform with accepted grammatical and communication standards required for effective daily functioning
      - b. Demonstrates effective written study skills including note taking, maintaining course specific journals, workbooks, manuals, etc.
      - c. Demonstrates technical writing skills in preparing outlines, summaries, time lines, flow charts, diagrams, etc. appropriate to materials covered
      - d. Demonstrates ability to complete all required writings in a timely, complete, and professional manner
      - e. Demonstrates competence in subject matter through the organization and presentation of answers to required written assessments

3. ***Arithmetic/Mathematics:*** *Perform basic computations and approaches practical problems by choosing appropriately from a variety of mathematical techniques*
    a. Demonstrates proficiency in basic arithmetic functions including ability to add, subtract, multiply, and divide whole numbers, fractions, decimals, and percentages
    b. Demonstrates ability to read, comprehend, and select appropriate math procedures to work basic math problems
    c. Demonstrates ability to understand and perform multi-step computations
    d. Demonstrates ability to read, interpret, and use standard measuring devices
    e. Demonstrates ability to comprehend, retain, and utilize course specific measuring devices effectively
    f. Demonstrates ability to understand, retain, and utilize higher mathematical formulas and functions required for course specific math performance
    g. Demonstrates ability to appropriately transfer mathematical calculations and information from paper to machines
4. ***Listening:*** *Receives, attends to, interprets, and responds to verbal messages and other cues*
    a. Functions at minimal or above required hearing levels to receive, attend, interpret, and respond to verbal messages and instructions and to safely operate machinery
    b. Demonstrates ability to hear, comprehend, and appropriately follow directions
    c. Demonstrates auditory ability to hear, comprehend, and utilize verbal classroom as well as other auditory instruction
    d. Demonstrates ability to discriminate between essential and non-essential verbal information and react appropriately
    e. Demonstrates ability to focus and fine-tune listening skills to receive, interpret, and respond to various sounds
    f. Demonstrates ability and maturity to seek and receive additional individualized instruction as needed
5. ***Speaking*:** *Organizes ideas and communicates orally*
    a. Demonstrates appropriate listening and speaking skills in personal conversations
    b. Demonstrates ability to choose and organize appropriate words to effectively communicate

c. Demonstrates ability to speak clearly and distinctly with appropriate volume, tone, and body language for situation
d. Demonstrates ability to spontaneously organize and present appropriate answers and/or short presentations for classroom and /or assessment purposes
e. Demonstrates ability to formulate, organize, and deliver major presentations to peers or groups
f. Demonstrates ability to speak effectively in one-on-one, small group, or large group presentations
g. Demonstrates ability to take responsibility for presentations

B. **Thinking Skills:** Thinks creatively, makes decisions, solves problems, visualizes, knows how to learn and reasons

*1. **Decision Making:** Specifies goals and constraints, generates alternatives, considers risks, and evaluates and chooses best alternative*

a. Demonstrates ability to objectively assess personal strengths and weaknesses
b.. Demonstrates ability to set realistic short-term and long-term goals
c. Demonstrates ability to recognize and distinguish between positive and negative alternatives
d. Demonstrates ability to identify potential pitfalls and take evasive actions
e. Demonstrates ability to objectively and responsibly evaluate alternatives by testing hypotheses and selecting most appropriate response
f. Demonstrates ability to profit from negative evaluations or mistakes by reformulating, redirecting, reconstructing, or retesting alternatives
g. Demonstrates maturity in taking responsibility for decisions

*2. **Problem Solving:** Recognizes problems and devises and implements plan of action*

a. Demonstrates ability to detect problem through observation, inquiry, or directive
b. Demonstrates ability to grasp appropriate overview and degree of seriousness of problem and to behave responsibly in situation
c. Demonstrates ability to generate alternatives or options for problem solution
d. Demonstrates ability to research options, assess and evaluate options, and determine appropriate and best solution

        - e. Demonstrates ability to initiate and effect solution
        - f. Demonstrates ability to take responsibility for outcomes
        - g. Demonstrates ability to effectively problem solve in individual, team, or group situations
    - 3. ***Seeing Things In the Mind's Eye:*** *Organizes, and processes symbols, pictures, graphs, objects, and other information*
        - a. Functions at minimum or above required visual levels in order to see, interpret, attend and respond to visual imagery and meet safety requirements for necessary machinery
        - b. Demonstrates ability to read, interpret, and act upon signs, symbols, and other visual cues
        - c. Demonstrates ability to visually discriminate in gross and fine imagery
        - d. Demonstrates ability to visualize abstractly
        - e. Demonstrates ability to apply visual imagery to applied tasks
    - 4. ***Knowing How to Learn:*** *Use efficient learning techniques to acquire and apply new knowledge and skills*
        - a. Demonstrates mastery of basic reading, math, and language skills through application
        - b. Demonstrates ability to translate abstract theory into practical application
        - c. Demonstrates ability to incorporate and generalize new learning into a sequential learning process
        - d. Demonstrates knowledge of good study skills and learning habits
    - 5. ***Reasoning:*** *Discovers a rule or principle underlying the relationship between two or more objects and applies it when solving a problem*
        - a. Demonstrates use of simple logic
        - b. Demonstrates ability to distinguish relationships
        - c. Demonstrates ability to determine and isolate factors in relationships
        - d. Demonstrates and applies knowledge through practice
        - e. Recognizes that attitudes, skills, and practice are essential to productivity
        - f. Demonstrates ability to discriminate between positive and negative, and act accordingly
- C. **Personal Qualities:** Displays responsibility, self-esteem, sociability, self-management, and integrity and honesty
    - 1. ***Responsibility:*** *Exerts a high level of effort and perseveres towards goal attainment*

    a. Demonstrates ability to formulate realistic and useful short and long term goals and complete steps necessary to timely achieve goals
    b. Demonstrates ability to make adjustments, revisions, and changes to achieve goals in a cooperative and polite manner
    c. Demonstrates ability to focus on task at hand and work to completion
    d. Demonstrates good work ethics through regular attendance, adequate classroom preparations, and appropriate use of classroom time
    e. Demonstrates maturity to take responsibility for actions
    f. Demonstrates ability to cooperatively work in individual, team, and group situations in timely and effective manner

2. ***Self-Esteem:*** *Believes in own self-worth and maintains a positive view of self*
    a. Presents a positive attitude toward tasks
    b. Demonstrates ability to separate work and personal behaviors
    c. Actively participates in learning opportunities by sharing knowledge and skills with peers and instructors
    d. Demonstrates ability to accept personal strengths and weaknesses and builds on positive behaviors
    e. Demonstrates ability to accept and use constructive criticism
    f. Accepts positive reinforcement in an appropriate manner
3. ***Sociability:*** *Demonstrates understanding, friendliness, adaptability, empathy, and politeness in group settings*
    a. Demonstrates appropriate and acceptable social behaviors in interactions
    b. Demonstrates ability to work cooperatively in individual, team, or group situations
    c. Demonstrates active interest in peers by offering assistance, sharing resources, and sharing knowledge in a professional and acceptable manner
    d. Demonstrates professional work ethic by separating work and personal social behaviors and acting accordingly
4. ***Self-Management:*** *Assesses self accurately, sets personal goals, monitors progress, and exhibits self-control*
    a. Accepts personal strengths and weaknesses and uses the same for positive advancement

- b. Demonstrates ability to continuously set, assess, choose, and modify objectives as the situation demands in an appropriate manner
- c. Demonstrates ability to formulate and follow personal schedules
- d. Demonstrates ability to wisely use classroom time
- e. Demonstrates use of good study habits and skills
- f. Demonstrates maturity to take responsibility for own actions

5. *Integrity/Honesty: Chooses ethical courses of action*
    - a. Knows and demonstrates ability to distinguish between positive and negative behaviors
    - b. Demonstrates honesty and integrity in working with peers and supervisors
    - c. Takes full responsibility for personal actions
    - d. Demonstrates understanding of consequences for negative ethical behaviors and accepts responsibility for same when applicable
    - e. Demonstrates positive work and social ethics in undertakings

Appropriate Reference Materials:

1. MASTER Technical Modules:
    CNC-A1 through CNC-A5;
    CNC-B1 through CNC-B8;
    CNC-C1 through CNC-C10;
    CNC-E1 through CNC-E6;
    CNC-G1 through CNC-G4; and,
    CNC-H1 through CNC-H5.
2. *Fanuc 6T Programming Manual,* Latest Edition
3. *Dynapath Lathe Manual,* Latest Edition
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5. *Anilam Lathemate Program Manuals,* Latest Edition

CNC 191

MASTER PROGRAM

Applications of CNC Controlled Turning I

COURSE SYLLABUS

Total lecture hours: 0 **Total lab hours: 96** **Credit hours: 2**

COURSE DESCRIPTION:

Exercises in CNC Turning techniques at an intermediate level. Emphasis placed on basic operations of CNC Turning. This class is designed to allow the student the opportunity to gain speed and efficiency in the hands on application of Turning operations at an intermediate level. Students in this class are expected to have previous machining experience.

PREREQUISITES: **Introduction to CNC Controlled Turning or concurrent enrollment**

COURSE OBJECTIVES:

After successful completion of this course, the students will be able to:

1. Identify CNC Lathes and their controls and accessories to complete specific operations;
2. Use verification software to analyze the effects of speeds, feeds, and depth of cut and total volume of material removal with an intermediate level of quality and quantity of projects;
3. Demonstrate the proper set up procedures for the Webb–Ecostar, ANILAM Lathemate, and Bendix CNC lathes using soft–jaws;
4. Demonstrate proper use of Controller to modify subroutines and macros;
5. Demonstrate an intermediate understanding of the common "G" and "M" codes as used on CNC Machines to create various programs;
6. Complete assigned projects using required skills with limited hands-on instruction by the instructor;
7. Demonstration reading and writing skills to read and prepare required documents for course work; and,
8. Demonstrate communication skills to interact successfully with members of working teams and instructor.

REQUIRED COURSE MATERIALS:

Textbooks: *Technology of Machine Tools,* Latest Edition, or
Fundamentals of Numerical Control, Latest Edition, or

Computer Numerical Control: From Programming to Networking, Latest Edition

Lab Manual: None

Supplies:

Computer Diskettes

METHOD OF INSTRUCTION

Lecture: Presentations will include lecture, with or without various audio–visual aids; discussion, debate, and/or critique; demonstration; computer–assisted or other self–paced instruction; field trips or field assignments.

Laboratory: Laboratory will be a hands–on process.

Method of Evaluation: A student's grade will be based on multiple measures of performance. The assessment will measure development of independent critical thinking skills and will include evaluation of the student's ability to:

1. Perform the manipulative skills of the craft as required to satisfactorily complete laboratory assignments;
2. Apply theory to laboratory assignments;
3. Satisfactorily perform on written, oral, or practical examinations;
4. Satisfactorily perform on outside assignments including writing assignments;
5. Contribute to class discussions;
6. Maintain attendance per current policy; and,
7. Follow all laboratory rules and safety regulations.

LAB OUTLINE:

Lab Topics	Contact Hrs.
Total Lab Hours	**96**

COURSE OBJECTIVES: SCANS COMPETENCIES

The Secretary's Commission on Achieving Necessary Skills (SCANS), U.S. Department of Labor, has identified in its "AMERICA 2000 REPORT" that all students should develop a new set of competencies and foundation skills if they are to enjoy a productive, full and satisfying life. These are in addition to the Technical Workplace Competencies required by industry. SCANS is made up of five competencies and a three-part *foundation of skills and personal qualities that are needed for solid job performance. All italicized headings in this section are direct quotations from "What Work Requires of Schools: A SCANS Report for America 2000."*

The following activities will be performed by each student for successful completion of this course:

I. COMPETENCIES
   A. *Resources: Identifies, organizes, plans, and allocates resources*
      1. Allocates time to complete assigned tasks on schedule
      2. Determines and allocates required materials and resources for meeting objectives
      3. Evaluates skills, performance, and quality of work and provides feedback
   B. *Interpersonal: Works with others*
      1. Participates as a member of the team, contributing to group effort
      2. Provides individual assistance/direction to peers as requested
      3. Determines and meets expectations
      4. Exercises leadership qualities to effectively communicate ideas and make decisions.
      5. Negotiates resources in order to accomplish objectives
      6. Works well with all members of the class
   C. *Information: Acquires and uses information*
      1. Acquires and evaluates information
      2. Organizes and maintains information
      3. Interprets and communicates information
   D. *Systems: Understands complex inter-relationships*
      1. Understands and works well with social, organizational, and technological systems
      2. Monitors and corrects performance of system during operation
      3. Recommends modifications to system to improve performance
   E. *Technology: Works with a variety of technologies*
      1. Chooses relevant procedures, tools, and equipment
      2. Applies appropriate procedures and techniques to accomplish tasks
      3. Identifies or solves problems to maintain equipment

II. FOUNDATION SKILLS
   A. **Basic Skills:** Reads, writes, performs arithmetic and mathematical operations, listens and speaks

1. *Reading: Locates, understands, and interprets written information in prose and in documents such as manuals, graphs, and schedules*
    a. Demonstrates basic reading skills including abilities to perceive main ideas, draw appropriate conclusions, detect a sequence, locate answers, find facts, and infer from written texts
    b. Demonstrates course specific reading skills including abilities to read, interpret, and comprehend information from text and supplemental materials on a level to facilitate productive independent and group study
    c. Demonstrates ability to read, interpret, and utilize information from course specific instruments (i.e., charts, diagrams, graphs, schematics, blueprints, flow charts, etc.)
    d. Demonstrates ability to read, interpret, and follow schedules and procedural instructions in a timely and appropriate manner
    e. Demonstrates ability to choose and use most appropriate reading method (skim, scan, or read for comprehension) for materials
2. *Writing: Communicates thoughts, ideas, information, and messages in writing; and creates documents such as letters, directions, manuals, reports, graphs, and flow charts*
    a. Demonstrates basic writing skills including abilities to produce written documents which conform with accepted grammatical and communication standards required for effective daily functioning
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- g. Demonstrates ability to appropriately transfer mathematical calculations and information from paper to machines

4. ***Listening:*** *Receives, attends to, interprets, and responds to verbal messages and other cues*
    - a. Functions at minimal or above required hearing levels to receive, attend, interpret, and respond to verbal messages and instructions and to safely operate machinery
    - b. Demonstrates ability to hear, comprehend, and appropriately follow directions
    - c. Demonstrates auditory ability to hear, comprehend, and utilize verbal classroom as well as other auditory instruction
    - d. Demonstrates ability to discriminate between essential and non-essential verbal information and react appropriately
    - e. Demonstrates ability to focus and fine-tune listening skills to receive, interpret, and respond to various sounds
    - f. Demonstrates ability and maturity to seek and receive additional individualized instruction as needed
5. ***Speaking:*** *Organizes ideas and communicates orally*
    - a. Demonstrates appropriate listening and speaking skills in personal conversations
    - b. Demonstrates ability to choose and organize appropriate words to effectively communicate
    - c. Demonstrates ability to speak clearly and distinctly with appropriate volume, tone, and body language for situation

    d. Demonstrates ability to spontaneously organize and present appropriate answers and/or short presentations for classroom and /or assessment purposes
    e. Demonstrates ability to formulate, organize, and deliver major presentations to peers or groups
    f. Demonstrates ability to speak effectively in one-on-one, small group, or large group presentations
    g. Demonstrates ability to take responsibility for presentations

B. **Thinking Skills:** Thinks creatively, makes decisions, solves problems, visualizes, knows how to learn and reasons

  1. ***Decision Making:*** *Specifies goals and constraints, generates alternatives, considers risks, and evaluates and chooses best alternative*
    a. Demonstrates ability to objectively assess personal strengths and weaknesses
    b. Demonstrates ability to set realistic short-term and long-term goals
    c. Demonstrates ability to recognize and distinguish between positive and negative alternatives
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        b. Demonstrates ability to read, interpret, and act upon signs, symbols, and other visual cues
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        d. Demonstrates ability to visualize abstractly
        e. Demonstrates ability to apply visual imagery to applied tasks
    4. ***Knowing How to Learn:*** *Use efficient learning techniques to acquire and apply new knowledge and skills*
        a. Demonstrates mastery of basic reading, math, and language skills through application
        b. Demonstrates ability to translate abstract theory into practical application
        c. Demonstrates ability to incorporate and generalize new learning into a sequential learning process
        d. Demonstrates knowledge of good study skills and learning habits
    5. ***Reasoning:*** *Discovers a rule or principle underlying the relationship between two or more objects and applies it when solving a problem*
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2. *Self-Esteem: Believes in own self-worth and maintains a positive view of self*
    - a. Presents a positive attitude toward tasks
    - b. Demonstrates ability to separate work and personal behaviors
    - c. Actively participates in learning opportunities by sharing knowledge and skills with peers and instructors
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    - b. Demonstrates ability to continuously set, assess, choose, and modify objectives as the situation demands in an appropriate manner
    - c. Demonstrates ability to formulate and follow personal schedules

    d. Demonstrates ability to wisely use classroom time
    e. Demonstrates use of good study habits and skills
    f. Demonstrates maturity to take responsibility for own actions

5. *Integrity/Honesty: Chooses ethical courses of action*
    a. Knows and demonstrates ability to distinguish between positive and negative behaviors
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4. *Greco Systems Manual,* Latest Edition
5. *ANILAM Lathemate Program Manuals,* Latest Edition
6. *Anilam Vertical Machining Program Manual,* Latest Edition

CNC 191
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MACHINE TOOL ADVANCED SKILLS TECHNOLOGY EDUCATIONAL RESOURCES

MASTER

a consortium of educators and industry

EDUCATIONAL RESOURCES
FOR THE
MACHINE TOOL INDUSTRY

Advanced CNC and CAM Series
INSTRUCTOR'S HANDBOOK

Supported by the National Science Foundation's Advanced Technological Education Program

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National Science Foundation
Advanced Technological
Education Program

"Any opinions, findings, and conclusions or recommendations
expressed in this material are those of the author(s) and do
not necessarily reflect the views of the Foundation."

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National Science Foundation - Division of Undergraduate Education
MASTER Consortia of Employers and Educators

MASTER has built upon the foundation which was laid by the Machine Tool Advanced Skills Technology (MAST) Program. The MAST Program was supported by the U.S. Department of Education - Office of Vocational and Adult Education. Without this prior support MASTER could not have reached the level of quality and quantity that is contained in these project deliverables.

MASTER DEVELOPMENT CENTERS

Augusta Technical Institute - Central Florida Community College - Itawamba Community College - Moraine Valley Community College - San Diego City College (CACT) - Springfield Technical Community College - Texas State Technical College

INDUSTRIES

AB Lasers - AIRCAP/MTD - ALCOA - American Saw - AMOCO Performance Products - Automatic Switch Company - Bell Helicopter - Bowen Tool - Brunner - Chrysler Corp. - Chrysler Technologies - Conveyor Plus - Darr Caterpillar - Davis Technologies - Delta International - Devon - D. J. Plastics - Eaton Leonard - EBTEC - Electro-Motive - Emergency One - Eureka - Foster Mold - GeoDiamond/Smith International - Greenfield Industries - Hunter Douglas - Industrial Laser - ITT Engineered Valve - Kaiser Aluminum - Krueger International. - Laser Fare - Laser Services - Lockheed Martin - McDonnell Douglas - Mercury Tool - NASSCO - NutraSweet - Rapistan DEMAG - Reed Tool - ROHR, International - Searle - Solar Turbine - Southwest Fabricators - Smith & Wesson - Standard Refrigeration - Super Sagless - Taylor Guitars - Tecumseh - Teledyne Ryan - Thermal Ceramics - Thomas Lighting - FMC, United Defense - United Technologies Hamilton Standard

COLLEGE AFFILIATES

Aiken Technical College - Bevil Center for Advanced Manufacturing Technology - Chicago Manufacturing Technology Extension Center - Great Lakes Manufacturing Technology Center - Indiana Vocational Technical College - Milwaukee Area Technical College - Okaloosa-Walton Community College - Piedmont Technical College - Pueblo Community College - Salt Lake Community College - Spokane Community College - Texas State Technical Colleges at Harlington, Marshall, Sweetwater

FEDERAL LABS

Jet Propulsion Lab - Lawrence Livermore National Laboratory - L.B.J. Space Center (NASA) - Los Alamos Laboratory - Oak Ridge National Laboratory - Sandia National Laboratory - Several National Institute of Standards and Technology Centers (NIST) - Tank Automotive Research and Development Center (TARDEC) - Wright Laboratories

SECONDARY SCHOOLS

Aiken Career Center - Chicopee Comprehensive High School - Community High School (Moraine, IL) - Connally ISD - Consolidated High School - Evans High - Greenwood Vocational School - Hoover Sr. High - Killeen ISD - LaVega ISD - Lincoln Sr. High - Marlin ISD - Midway ISD - Moraine Area Career Center - Morse Sr. High - Point Lamar Sr. High -

Pontotoc Ridge Area Vocational Center - Putnam Vocational High School - San Diego Sr. High - Tupelo-Lee Vocational Center - Waco ISD - Westfield Vocational High School

ASSOCIATIONS

American Vocational Association (AVA) - Center for Occupational Research and Development (CORD) - CIM in Higher Education (CIMHE) - Heart of Texas Tech-Prep - Midwest (Michigan) Manufacturing Technology Center (MMTC) - National Coalition For Advanced Manufacturing (NACFAM) - National Coalition of Advanced Technology Centers (NCATC) - National Skills Standards Pilot Programs - National Tooling and Machining Association (NTMA) - New York Manufacturing Extension Partnership (NYMEP) - Precision Metalforming Association (PMA) - Society of Manufacturing Engineers (SME) - Southeast Manufacturing Technology Center (SMTC)

MASTER PROJECT EVALUATORS

Dr. James Hales, East Tennessee State University and William Ruxton, formerly with the National Tooling and Machine Association (NTMA)

NATIONAL ADVISORY COUNCIL MEMBERS

The National Advisory Council has provided input and guidance into the project since the beginning. Without their contributions, MASTER could not have been nearly as successful as it has been. Much appreciation and thanks go to each of the members of this committee from the project team.

Dr. Hugh Rogers-Dean of Technology-Central Florida Community College
Dr. Don Clark-Professor Emeritus-Texas A&M University
Dr. Don Edwards-Department of Management-Baylor University
Dr. Jon Botsford-Vice President for Technology-Pueblo Community College
Mr. Robert Swanson-Administrator of Human Resources-Bell Helicopter, TEXTRON
Mr. Jack Peck-Vice President of Manufacturing-Mercury Tool & Die
Mr. Don Hancock-Superintendent-Connally ISD

SPECIAL RECOGNITION

Dr. Hugh Rogers recognized the need for this project, developed the baseline concepts and methodology, and pulled together industrial and academic partners from across the nation into a solid consortium. Special thanks and singular congratulations go to Dr. Rogers for his extraordinary efforts in this endeavor.

Dr. Don Pierson served as the Principal Investigator for the first two years of MASTER. His input and guidance of the project during the formative years was of tremendous value to the project team. Special thanks and best wishes go to Dr. Pierson during his retirement and all his worldly travels.

All findings and deliverables resulting from MASTER are primarily based upon information provided by the above companies, schools and labs. We sincerely thank key personnel within these organizations for their commitment and dedication to this project. Including the national survey, more than 2,800 other companies and organizations participated in this project. We commend their efforts in our combined attempt to reach some common ground in precision manufacturing skills standards and curriculum development.

MASTER DEVELOPMENT CENTER, SAN DIEGO, CA
Center for Applied Competitive Technologies
San Diego City College

Augustine P. Gallego, Chancellor
San Diego Community College District
Jerome Hunter, President
San Diego City College
Joan A. Stepsis, Dean/Director
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Manufacturing in the San Diego Region

Manufacturing represents a major sector of the San Diego economy, accounting for almost one out of every four dollars (24%) of San Diego's gross regional product. The county is currently home to approximately 3,500 manufacturers employing roughly 110,000 San Diegans. During the first half of the 1990s, manufacturing in San Diego was hard hit by the downturn in military and defense spending which accompanied the end of the cold war. Many of the region's largest aerospace contractors rapidly downsized or moved their plants out of state, leaving a large supplier base that needed to modernize its manufacturing processes and convert to commercial markets. Rapid recovery of manufacturing in the region has been driven by San Diego's high tech research and development sectors in electronics, telecommunications, software, advanced materials, biotechnology, and medical instrumentation.

San Diego City College and its Center for Applied Competitive Technologies (CACT)

San Diego City College is an urban, minority institution, serving a large population of students from immigrant, disadvantaged, and low income households. In 1990, the College saw an opportunity to modernize its technical programs and improve the employment outlook for many of its students by agreeing to host one of the State of California's eight new regional manufacturing extension centers, the Centers for Applied Competitive Technologies (CACTs). The advanced technology centers were designed to assist local companies to modernize their manufacturing processes and convert from defense to newly emerging, technology-based commercial markets. This strategic partnership between the College and its resident CACT has proven to be highly successful. In developing the programs and lab facilities to serve the needs of regional manufacturing companies, the San Diego CACT and City College have simultaneously modernized the manufacturing and machine technology credit offerings of the College, thereby providing a well-trained, technically competent workforce for industry and enhancing career opportunities for students.

Development Team

- **Project Director:** Joan A. Stepsis, Ph.D., Dean/Director of the CACT-SD, served as programmatic manager and academic coordinator for the MASTER project.
- **Subject Matter Expert:** John C. Bollinger, Assoc. Prof. of Machine Technology, had programmatic responsibility for developing skill standards and course/program materials for the Advanced CNC and CAM component of the MASTER project. Professor Bollinger also served as the lead instructor for the MASTER instructional pilot for his specialty area.
- **Subject Matter Expert:** Douglas R. Welch, Assoc. Prof. of Manufacturing, had programmatic responsibility for developing skill standards and course/program materials for the Automated Equipment Technology (AET) and Machine Tool Integration (CIM) component of the MASTER project. Professor Welch also served as lead instructor for the MASTER instructional pilot for his specialty area.

Introduction:
INSTRUCTOR'S HANDBOOK

Prior to the development of this Instructor's Handbook, MASTER project staff visited over 150 companies, conducted interviews with over 500 expert workers, and analyzed data from a national survey involving over 2800 participating companies. These investigations led to the development of a series of Instructor Handbooks, with each being fully industry-driven and specific to one of the technologies shown below.

Advanced CNC and CAM
Automated Equipment Repair
Computer Aided Design & Drafting
Conventional Machining
Industrial Maintenance
Instrumentation
LASER Machining
Manufacturing Technology
Mold Making
Tool And Die
Welding

Each Instructor's Handbook contains a collection of Technical Training Modules which are built around a Competency Profile for the specific occupation. **The Competency Profile which is the basis for this Instructor's Handbook, may be found on the following page (and on each of the tab pages of this book).**

Each Technical Training Module has been designed to be:

- Based on skill standards specified by industry. There must be a direct correlation between what industry needs and what is taught in the classroom and in the laboratory. For many years this type of training has been known as "competency-based training".

- Generic in nature. The training materials may then be customized by the trainer, for any given training situation based on the training need.

- Modular in design, to allow trainers to select lessons which are applicable to their training needs.

- Comprehensive, include training for advanced and emerging, highly-specialized manufacturing technologies.

- Self-contained, including all the components which might be needed by an experienced trainer. These components might include any or all of the following:
  - a standardized lesson plan,
  - an assessment instrument,
  - a listing of commercially available resources (e.g. recommended textbooks, instructor guides, student manuals, and videos),
  - new training materials, when suitable existing materials are not available (e.g., classroom handouts, transparency masters, and laboratory exercises).

This Instructor's Handbook is arranged by Duty groupings (Duty A, Duty B, etc.) with technical modules developed for each Task Box on the Competency Profile. Trainers are free to choose modules for a specific training need and combine modules to build individualized training programs.

This Instructor's Handbook is being offered with an accompanying Student Laboratory Manual for use by the students enrolled in the training program.

CNC MACHINIST .... programs, edits, sets up, and operates CNC lathes, mills and grinders to perform machining operations necessary to produce workpieces to referenced engineering standards.

Duties		Tasks												
A	Practice Safety	A-1 Follow safety manuals and all safety regulations/ requirements	A-2 Use protective equipment	A-3 Follow safe operating procedures for hand and machine tools	A-4 Maintain a clean and safe work environment	A-5 MSDS/ control chemical hazards								
B	Apply Mathematical Concepts	B-1 Perform basic arithmetic functions	B-2 Convert fractional/ decimals	B-3 Convert Metric/ English measurements	B-4 Perform basic algebraic operations	B-5 Use practical geometry	B-6 Understand basic trigonometry	B-7 Calculate speeds and feeds for machining	B-8 Use coordinate systems					
C	Interpret Engineering Drawings and Control Documents	C-1 Identify basic layout of drawings	C-2 Identify basic types of drawings	C-3 Review blueprint notes and dimensions	C-4 List the purpose of each type of drawing	C-5 Verify drawing elements	C-6 Practice Geometric Dimensioning and Tolerancing (GD&T)	C-7 Analyze bill of materials (BOM)	C-8 Describe the relationship of engineering drawings to planning	C-9 Understand and use quality systems	C-10 Verify standard requirements			
D	Recognize Different Manufacturing Materials and Processes	D-1 Identify materials with desired properties	D-2 Identify materials and processes to produce a part	D-3 Describe the heat treating process	D-4 Test metal samples for hardness	D-5 Understand welding operations								
E	Measure/ Inspect	E-1 Understand metrology terms	E-2 Select measurement tools	E-3 Measure with hand held instruments	E-4 Eliminate measurement variables	E-5 Measure/ inspect using surface plate and accessories	E-6 Inspect using stationary equipment							
F	Perform Conventional Machining	F-1 Prepare and plan for machining operations	F-2 Use hand tools	F-3 Operate power saws	F-4 Operate drill presses	F-5 Operate vertical milling machines	F-6 Operate horizontal milling machines	F-7 Operate metal cutting lathes	F-8 Operate grinding/ abrasive machines					
G	Perform Advanced Machining	G-1 Understand CNC basics	G-2 Program CNC machines	G-3 Operate CNC machining centers (mills)	G-4 Operate CNC turning centers (lathes)									
H	Use Verification and Communication Systems	H-1 Use personal computer	H-2 Use various operating systems	H-3 Use computer communications systems	H-4 Use verification systems	H-5 Use the Internet								
I	Program Using CAM System	I-1 Understand CAD/ CAM programs	I-2 Manipulate CAD functions	I-3 Process simple tool-path data	I-4 Create advanced surface models	I-5 Process complex tool-path functions								

CNC MACHINIST .... **programs, edits, sets up, and operates CNC lathes, mills and grinders to perform machining operations necessary to produce workpieces to referenced engineering standards.**

Duties		Tasks												
A	Practice Safety	A-1 Follow safety manuals and all safety regulations/ requirements	A-2 Use protective equipment	A-3 Follow safe operating procedures for hand and machine tools	A-4 Maintain a clean and safe work environment	A-5 MSDS/ control chemical hazards								
B	Apply Mathematical Concepts	B-1 Perform basic arithmetic functions	B-2 Convert fractions/ decimals	B-3 Convert Metric/ English measurements	B-4 Perform basic algebraic operations	B-5 Use practical geometry	B-6 Understand basic trigonometry	B-7 Calculate speeds and feeds for machining	B-8 Use coordinate systems					
C	Interpret Engineering Drawings and Control Documents	C-1 Identify basic layout of drawings	C-2 Identify basic types of drawings	C-3 Review blueprint notes and dimensions	C-4 List the purpose of each type of drawing	C-5 Verify drawing elements	C-6 Practice Geometric Dimensioning and Tolerancing (GD&T)	C-7 Analyze bill of materials (BOM)	C-8 Describe the relationship of engineering drawings to planning	C-9 Understand and use quality systems	C-10 Verify standard requirements			
D	Recognize Different Manufacturing Materials and Processes	D-1 Identify materials with desired properties	D-2 Identify materials and processes to produce a part	D-3 Describe the heat treating process	D-4 Test metal samples for hardness	D-5 Understand welding operations								
E	Measure/ Inspect	E-1 Understand metrology terms	E-2 Select measurement tools	E-3 Measure with hand held instruments	E-4 Eliminate measurement variables	E-5 Measure/ inspect using surface plate and accessories	E-6 Inspect using stationary equipment							
F	Perform Conventional Machining	F-1 Prepare and plan for machining operations	F-2 Use hand tools	F-3 Operate power saws	F-4 Operate drill presses	F-5 Operate vertical milling machines	F-6 Operate horizontal milling machines	F-7 Operate metal cutting lathes	F-8 Operate grinding/ abrasive machines					
G	Perform Advanced Machining	G-1 Understand CNC basics	G-2 Program CNC machines	G-3 Operate CNC machining centers (mills)	G-4 Operate CNC turning centers (lathes)									
H	Use Verification and Communication Systems	H-1 Use personal computer	H-2 Use various operating systems	H-3 Use computer communications systems	H-4 Use verification systems	H-5 Use the Internet								
I	Program Using CAM System	I-1 Understand CAD/ CAM programs	I-2 Manipulate CAD functions	I-3 Process simple tool-path data	I-4 Create advanced surface models	I-5 Process complex tool-path functions								

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-A1

Subject: **Advanced CNC and CAM** **Time: 2 Hrs.**

Duty: **Practice Safety**
Task: Follow Safety Manuals and All Safety Regulations/ Requirements

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Objective(s):

Upon completion of this unit the student will be able to:

a. Assume responsibility for the personal safety of oneself and others;
b. Develop a personal attitude towards safety;
c. Interpret safety manual directives;
d. Identify and control common machine shop hazards; and,
e. Comply with established company safety practices.

Instructional Materials:

MASTER Handout (CNC-A1-HO)
MASTER Laboratory Exercise (CNC-A1-LE)
MASTER Laboratory Aid (CNC-A1-LA)
MASTER Self-Assessment

References:

Specific Company Safety Policy and Procedures Manual
OSHA General Industry Requirements, U. S. Government Printing Office, Latest Edition

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Student Preparation:

All students must prepare themselves to enhance their attitudes toward safety. Such preparation may begin by the students asking themselves the following basic questions daily:

1. Is my hair properly stowed to prevent accidents?
2. Am I wearing any jewelry?
3. Do I have the proper shoes?
4. Do I have my eye shields (safety glasses)?
5. Is my work area free of debris and clean?
6. Does my machine have all its safeguards?
7. Is my machine working properly?
8. Do I know where the nearest fire extinguisher is?

Introduction:

Safety on the job is not only the responsibility of the management of the company. While management must establish rules according to regulations that the government has set forth for your industry, and while they must enforce these rules, every employee must be taught what these rules are and how to obey them. However, the responsibility for safety is in your hands. You are the person closest to the work being performed. Learn and follow all rules. Never take short cuts or chances. Make safety your way of life.

Presentation Outline:

I. Assume Responsibility for the Personal Safety of Oneself and Others
    A. Safety is a way of life not an option
    B. Always operate with alertness and safety foremost in mind
II. Develop a Personal Attitude Towards Safety
    A. The key to safety is individual safety
    B. Everyone must develop a safe attitude
    C. Each step of the operation must be carefully planned
III. Interpret Safety Manual Directives
    A. Read and understand safety manual
    B. Read machine operation instructions
IV. Comply with Established Safety Practices
    A. Personal safety
        1. Body: keep body out of line of tool edge
        2. Proper lifting technique
            a. Personal lifting
                1) Lift with the legs, not the back
                2) Proper physical position while lifting
                3) Proper clearance for carrying
                4) "Buddy system" for heavy lifting
            b. Equipment lifting
                1) Checking ratings for lifting devices
                2) Checking lifting points on lifted item
                3) Overhead clearance requirements
                4) Static lifting devices (slings, jack stands) should be used instead of moving lifting devices (jacks or forklifts) for actually holding heavy items up while working on them
    B. Eyes: always wear safety glasses
    C. Head: keep long hair up; wear hard hat whenever required
    D. Ears: wear protection to prevent damage from noise
    E. Jewelry: no rings, watches, bracelets, necklaces (they can get caught in machinery and they are conductors of electricity)

F. Clothing: keep sleeves and pant legs rolled down; and ties, strings, and belts away from moving parts
G. No horse-play
H. Do not talk to someone while that person is operating a machine
I. Do not talk to someone while you are operating a machine
V. Identify and Control Common Machine Shop Hazards
A. Chip formation
B. Moving machine parts
C. Spills and other debris
D. Electrical lines
E. Hydraulic and pneumatic lines
VI. Cover specific safety policies of the company

Practical Application:

The students must demonstrate a practical and aware attitude toward safety in the workplace at all times. No careless or unsafe behavior is acceptable.

NB: The laboratory exercise for this module is to be completed *before* the instruction begins. Laboratory Exercise CNC-A1-LE ties directly to the final laboratory exercise in the CNC-A Safety series.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-A2) dealing with the use of protective equipment.

CNC-A1-HO
Follow Safety Manuals and All Safety Regulations/Requirements
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

- a. Assume responsibility for the personal safety of oneself and others;
- b. Develop a personal attitude towards safety;
- c. Interpret safety manual directives;
- d. Identify and control common machine shop hazards; and,
- e. Comply with established company safety practices.

Module Outline:

- I. Assume Responsibility for the Personal Safety of Oneself and Others
  - A. Safety is a way of life not an option
  - B. Always operate with alertness and safety foremost in mind
- II. Develop a Personal Attitude Towards Safety
  - A. The key to safety is individual safety
  - B. Everyone must develop a safe attitude
  - C. Each step of the operation must be carefully planned
- III. Interpret Safety Manual Directives
  - A. Read and understand safety manual
  - B. Read machine operation instructions
- IV. Comply with Established Safety Practices
  - A. Personal safety
    - 1. Body: keep body out of line of tool edge
    - 2. Proper lifting technique
      - a. Personal lifting
        - 1) Lift with the legs, not the back
        - 2) Proper physical position while lifting
        - 3) Proper clearance for carrying
        - 4) "Buddy system" for heavy lifting
      - b. Equipment lifting
        - 1) Checking ratings for lifting devices
        - 2) Checking lifting points on lifted item
        - 3) Overhead clearance requirements
        - 4) Static lifting devices (slings, jack stands) should be used instead of moving lifting devices (jacks or forklifts) for actually holding heavy items up while working on them
  - B. Eyes: always wear safety glasses
  - C. Head: keep long hair up; wear hard hat whenever required

    - D. Ears: wear protection to prevent damage from noise
    - E. Jewelry: no rings, watches, bracelets, necklaces (they can get caught in machinery and they are conductors of electricity)
    - F. Clothing: keep sleeves and pant legs rolled down; and ties, strings, and belts away from moving parts
    - G. No horse-play
    - H. Do not talk to someone while that person is operating a machine
    - I. Do not talk to someone while you are operating a machine
- V. Identify and Control Common Machine Shop Hazards
    - A. Chip formation
    - B. Moving machine parts
    - C. Spills and other debris
    - D. Electrical lines
    - E. Hydraulic and pneumatic lines
- VI. Cover specific safety policies of the company

CNC-A1-LE
Follow Safety Manuals and All Safety Regulations/Requirements
Attachment 2: MASTER Laboratory Exercise

The purpose of this exercise is to learn to recognize hazards in the workplace. Many of the hazards which you will find there are common practices by people who simply no longer see the danger.

The instructor will guide all students through part of the facility. Each student should write down, in the space provided below, as many safety hazards as are found.

Remember, anyone can cause a hazard merely by failing to see the mop bucket that sits in front of the fire exit every day. Such tunnel vision is the result of familiarity and demonstrates the importance of keeping a fresh perspective *everyday*.

Due to the nature of this laboratory exercise, no answer key is possible.

Safety Hazards

Type	Location	Description

CNC-A1-LA
Follow Safety Manuals and All Safety Regulations/Requirements
Attachment 3: MASTER Laboratory Aid

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

Name________________________ Date______________

CNC-A1
Follow Safety Manuals and All Safety Regulations/Requirements
Self-Assessment

Circle the letter preceding the correct answer.

1. A positive attitude towards safety:
   A. Is the responsibility of the individual.
   B. Is the responsibility of management.
   C. Can be developed by all workers, regardless of their work.
   D. All of the above
   E. None of the above answers is correct.

2. When is jewelry permitted to be worn?
   A. On slow moving machinery
   B. If all guards are in place
   C. Never
   D. If your supervisor knows
   E. None of the above answers is correct.

3. Most accidents occur because:
   A. Almost every tool is unsafe.
   B. There is an unsafe condition and an unsafe action.
   C. Workers lack motivation.
   D. There is a practical joker in every plant.
   E. None of the above answers is correct.

4. Who is responsible for safety on the job?
   A. Management and employees
   B. Employees
   C. Union
   D. Government
   E. None of the above answers is correct.

5. Your most important motivation for working safely is to:
   A. Get a raise.
   B. Avoid being suspended.
   C. Protect yourself.
   D. Avoid working too hard.
   E. None of the above answers is correct.

6. Your best protection against accidents is often:
   A. Alertness.
   B. Union policy.
   C. Close supervision.
   D. Buddy system.
   E. None of the above answers is correct.

7. Which of the following three things is more important than natural skill in doing a job well and safely?
   A. Training
   B. Attitude
   C. Alertness
   D. All of the above
   E. None of the above answers is correct.

8. When you spot something dangerous in your plant, the first thing you should do is:
   A. Notify OSHA.
   B. Report it to your supervisor.
   C. Note it in the company safety log.
   D. Walk off the job.
   E. None of the above answers is correct.

9. OSHA regulations state that machines or equipment are safe after they are:
   A. Locked or tagged out.
   B. Turned off.
   C. Assumed de-energized.
   D. Written in the maintenance log.
   E. None of the above answers is correct.

10. Before operating machines, the operators should:
   A. Ask a co-worker.
   B. Operate them until they learn how.
   C. Read all the operating manuals.
   D. Wear gloves.
   E. None of the above answers is correct.

CNC-A1
Follow Safety Manuals and All Safety Regulations/Requirements
Self-Assessment Answer Key

1. D
2. C
3. B
4. A
5. C
6. A
7. D
8. B
9. A
10. C

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-A2

Subject: **Advanced CNC and CAM** **Time: 2 Hrs.**

Duty: **Practice Safety**
Task: Use Protective Equipment

Objective(s):

Upon completion of this unit the student will be able to:
a. Wear protective safety clothing as required;
b. Maintain and use protective guards and equipment on machinery;
c. Locate and properly use protective equipment; and,
d. Use lifting aids when necessary.

Instructional Materials:

MASTER Handout (CNC-A2-HO)
MASTER Laboratory Exercise (CNC-A2-LE)
MASTER Laboratory Aid (CNC-A2-LA)
MASTER Self-Assessment

References:

Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition, Unit 1
OSHA General Industry Requirements, U. S. Government Printing Office, Latest Edition

Student Preparation:

Students should have previously completed the following Technical Modules:
CNC-A1 "Follow Safety Manuals and All Safety Regulations/Requirements"

Introduction:

Safety is taught by schools and industries but it is up to the individual worker to put it into practice. Read the rules and regulations to know what clothing is safe for the job you are doing. Other manuals tell you how to safely operate and service machinery and equipment. There are also safety tips on how to lift or use lifting aids when moving or lifting is done. Being safe never takes as long as getting well.

Presentation Outline:

- I. Wear Protective Safety Clothing as Required
  - A. Different types of safety clothing
    - 1. Protective from debris, cuts, and blows
      - a. Hard hat, safety glasses or goggles, work gloves when necessary
      - b. Sturdy footwear
      - c. Long sleeved shirt (sleeves rolled down and buttoned)
    - 2. Fire-retardant and fire-resistant clothing
      - a. Long sleeved, 100% cotton shirt
      - b. Long pants, 100% cotton
      - c. Leather chest protector, sleeves
    - 3. Optical filters to protect vision from intense light
      - a. Welding hood or goggles
      - b. Safety glasses or goggles for grinding
      - c. Tinted goggles for cutting torch work
    - 4. Breathing protection
      - a. Mask for dust, lint, smoke
  - B. Function and use of safety clothing
    - 1. Man made fiber clothing melts to worker's skin when ignited
    - 2. Prevents cuts and abrasions
    - 3. Keep shirt sleeves rolled down (hangs on equipment)
    - 4. Do not cuff pant legs (causes tripping)
    - 5. Do not wear jewelry
      - a. Catches in moving parts
      - b. Conducts electricity
    - 6. Do not wear neckties around moving parts of machinery
    - 7. Keep belts and apron strings tied and away from moving equipment
- II. Maintain and Use Protective Guards and Equipment on Machinery
  - A. Purposes of various guards
    - 1. Do not operate a machine until guards are in place
    - 2. Stop the machine to make adjustments or repairs
    - 3. Disconnect power before removing guards or panels
  - B. Evaluation and maintenance of protective equipment
    - 1. Use only those electrical devices which have been approved by UL (Underwriters' Laboratories)
    - 2. Do not use defective equipment
    - 3. Report defective or unsafe equipment immediately
    - 4. Make sure equipment is properly grounded
- III. Locate and Properly Use Protective Equipment
  - A. Install safety barriers

B. Use caution signs
C. Install lock and tag devices
D. Know where fire extinguishers are and how to use them
IV. Use Lifting Aids When Necessary
A. Discuss recommended limits on single-person lifting
B. Discuss proper lifting methods (use of the legs)
1. Use your legs (bend your knees)
2. Keep the load close to your body
3. Don't twist your body while lifting
4. Make sure you can see where you are going
5. Wear support belts
C. Discuss team-lifting
1. Keep load the same height while lifting
2. Move and lift on command
3. Use dolly, wheelbarrow, or forklift
D. Determine lifting ratings of lifting equipment
1. Know how your forklift operates
2. Understand load characteristics (weight, size, shape)
E. Determine holding ratings of static lifting devices
F. Evaluate positions on the workpiece for placement of lifting and holding devices

Practical Application:

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-A3) dealing with the safe operating procedures for hand and machine tools.

CNC-A2-HO
Use Protective Equipment
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

- a. Wear protective safety clothing as required;
- b. Maintain and use protective guards and equipment on machinery;
- c. Locate and properly use protective equipment; and,
- d. Use lifting aids when necessary.

Module Outline:

- I. Wear Protective Safety Clothing as Required
  - A. Different types of safety clothing
    - 1. Protective from debris, cuts, and blows
      - a. Hard hat, safety glasses or goggles, work gloves when necessary
      - b. Sturdy footwear
      - c. Long sleeved shirt (sleeves rolled down and buttoned)
    - 2. Fire-retardant and fire-resistant clothing
      - a. Long sleeved, 100% cotton shirt
      - b. Long pants, 100% cotton
      - c. Leather chest protector, sleeves
    - 3. Optical filters to protect vision from intense light
      - a. Welding hood or goggles
      - b. Safety glasses or goggles for grinding
      - c. Tinted goggles for cutting torch work
    - 4. Breathing protection
      - a. Mask for dust, lint, smoke
  - B. Function and use of safety clothing
    - 1. Man made fiber clothing melts to worker's skin when ignited
    - 2. Prevents cuts and abrasions
    - 3. Keep shirt sleeves rolled down (hangs on equipment)
    - 4. Do not cuff pant legs (causes tripping)
    - 5. Do not wear jewelry
      - a. Catches in moving parts
      - b. Conducts electricity
    - 6. Do not wear neckties around moving parts of machinery
    - 7. Keep belts and apron strings tied and away from moving equipment
- II. Maintain and Use Protective Guards and Equipment on Machinery
  - A. Purposes of various guards

        1. Do not operate a machine until guards are in place
        2. Stop the machine to make adjustments or repairs
        3. Disconnect power before removing guards or panels
    B. Evaluation and maintenance of protective equipment
        1. Use only those electrical devices which have been approved by UL (Underwriters' Laboratories)
        2. Do not use defective equipment
        3. Report defective or unsafe equipment immediately
        4. Make sure equipment is properly grounded

III. Locate and Properly Use Protective Equipment
    A. Install safety barriers
    B. Use caution signs
    C. Install lock and tag devices
    D. Know where fire extinguishers are and how to use them

IV. Use Lifting Aids When Necessary
    A. Discuss recommended limits on single-person lifting
    B. Discuss proper lifting methods (use of the legs)
        1. Use your legs (bend your knees)
        2. Keep the load close to your body
        3. Don't twist your body while lifting
        4. Make sure you can see where you are going
        5. Wear support belts
    C. Discuss team-lifting
        1. Keep load the same height while lifting
        2. Move and lift on command
        3. Use dolly, wheelbarrow, or forklift
    D. Determine lifting ratings of lifting equipment
        1. Know how your forklift operates
        2. Understand load characteristics (weight, size, shape)
    E. Determine holding ratings of static lifting devices
    F. Evaluate positions on the workpiece for placement of lifting and holding devices

CNC-A2-LE
Use Protective Equipment
Attachment 2: MASTER Laboratory Exercise

The instructor will display as much protective equipment, such as welding masks, breathers, and hard hats as is practical and desirable. The instructor should demonstrate the proper use of this equipment.

Due to the nature of this exercise, no answer key is possible.

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

Name____________________________ Date_______________

CNC-A2
Use Protective Equipment
Self-Assessment

Circle the letter preceding the correct answer.

1. Back injuries, often from poor ________ are the most common type of serious occupational injury.
   A. Lifting techniques
   B. Muscle structure
   C. Attitude adjustment
   D. Warm-up

2. If a load is too heavy, get help or use a special:
   A. Lifting techniques.
   B. Mechanical device.
   C. Platforms.
   D. Friends.

3. When lifting or lowering from high places, stand on a:
   A. Ladder.
   B. Chair.
   C. Platform.
   D. Box.

4. Energy can be mechanical, _____________, hydraulic, or pneumatic.
   A. Powerful
   B. Electrical
   C. Inactive
   D. All of the above

5. One step in the lockout procedure is to ___________ to make sure the power is off.
   A. Test the operating controls
   B. Ask your supervisor
   C. Check with co-workers
   D. Turn switch off

6. Remember, ___________ alone don't prevent equipment from starting up.
   A. Locks
   B. Verbal instructions
   C. Tags
   D. All of the above

7. Which of the following are unsafe in the industrial workplace?
   - A. Jewelry
   - B. Man-made fiber clothing
   - C. Open-toe shoes
   - D. All of the above

8. Proper protection equipment for a welder always includes all of the following except:
   - A. Eye protection.
   - B. Ear protection.
   - C. Flame-resistant gloves.
   - D. Gas mask.

9. Ultraviolet rays are harmful when welding because they produce:
   - A. Intense heat.
   - B. Skin cancer.
   - C. Eye damage.
   - D. Metal fatigue.

10. In double insulated tools, protection against electric shock is provided by the:
    - A. Insulated case or liner.
    - B. Two-wire supply cord.
    - C. Three-wire supply cord.
    - D. Lug.

11. It is good practice to connect the neutral conductor and the metallic conduit of an electrical circuit to a common ground, because doing so:
    - A. Eliminates ground faults.
    - B. Provides more protection against shock.
    - C. Reduces fault current.
    - D. Improves the voltage in the circuit.

12. Damaged or deteriorated conductors on machinery or equipment should be:
    - A. Separated.
    - B. Replaced.
    - C. Taped.
    - D. Reported.

13. All equipment should be inspected before use.
    - A. True
    - B. False

14. Guards may be left off equipment for frequent servicing while the equipment is running.
  A. True
  B. False

15. It is permissible to loan your lock out key to co-workers.
  A. True
  B. False

CNC-A2
Use Protective Equipment
Self-Assessment Answer Key

1. A
2. B
3. C
4. B
5. A
6. C
7. D
8. D
9. C
10. A
11. B
12. B
13. A
14. B
15. B

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-A3

Subject: **Advanced CNC and CAM** **Time: 2 Hrs.**

Duty: **Practice Safety**
Task: Follow Safe Operating Procedures for Hand and Machine Tools

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Objective(s):

Upon completion of this unit the student will be able to:
a. Identify and understand safe machine operating procedures; and,
b. Demonstrate safe machine operation.

Instructional Materials:

MASTER Handout (CNC-A3-HO)
MASTER Laboratory Exercise (CNC-A3-LE)
MASTER Laboratory Aid (CNC-A3-LA)
MASTER Self-Assessment
Operation manuals for all covered machines

References:

Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition, Unit 1
OSHA General Industry Requirements, U. S. Government Printing Office, Latest Edition

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Student Preparation:

Students should have previously completed the following Technical Modules:
CNC-A1 "Follow Safety Manuals and All Safety Regulations/Requirements"
CNC-A2 "Use Protective Equipment"

Introduction:

The reason that there are safety guards on machines is to prevent accidents. Read the operating manuals and train for the operation of the machine before attempting to use it. You cannot always tell whether a part is moving or energized by just looking at it. Before working on the machine, always bring the machine to a zero energy state. The more you learn about the machine, the safer and easier your work will be.

Presentation Outline:

I. Identify and Understand Safe Machine Operating Procedures
   A. Never make adjustments on a machine while it is running
      1. Keep guards in place at all times
      2. Discontinue power before servicing
      3. Keep body parts clear of moving machinery
      4. Beware of sharp edges and flying debris
      5. Secure work pieces to prevent slipping
      6. Never stand directly in line with blades or knives
      7. Avoid kickback
      8. Feed stack into machine correctly
   B. Electrical safety
      1. Use only those electrical devices which have been approved by UL (Underwriters' Laboratories)
      2. Stand on dry surface when working on electrical equipment
      3. Replace defective cords or plugs on equipment
      4. Use only those tools that are in good condition
      5. Use only carbon dioxide or dry chemical fire extinguishers for control of electrical fires
      6. Obtain help when working on equipment that may become energized
   C. Avoid horseplay and practical jokes
   D. Keep work area clean.

II. Demonstrate Safe Machine Operation
   A. Good housekeeping
      1. Materials and equipment should be stacked straight and neat
      2. Keep aisles and walkways clear of tools, materials, and debris
      3. Dispose of scraps and rubbish daily
      4. Clean up spills
      5. Clean and store hand tools
   B. Good techniques
      1. Always walk - do not run
      2. Never talk to or interrupt anyone who is operating a machine
      3. Never leave tools or pieces of stock lying on table surface of a machine being used
      4. When finished with a machine, turn power OFF and wait until blades or cutters have come to a complete stop before leaving
      5. Check stock for defects before machining
         a. Do not use a machine until you understand it thoroughly
         b. Do not jam or rush stock into machinery
         c. Keep guards in place
         d. Make sure power is OFF before working on or servicing

6. Keep hands and fingers away from moving parts
7. Don't try to run too small a piece through the machine
8. Use a brush to clean the surface table
9. Keep your eyes focused on what you are working on
10. Never use an air hose to blow debris off yourself or other workers
11. Report faulty machinery to your supervisor
12. Make sure machinery is properly grounded
13. Never leave a piece of machinery that is running unattended
14. Make sure stack is solidly supported

C. Miscellaneous materials
   1. Molten metal - can splash and cause serious burns
   2. Chemicals - burn or irritate the skin or cause eye damage
   3. Broken glass - causes cuts, can get in the eyes
   4. Pointed objects - knives, screwdrivers, punches, staples can puncture the skin
   5. Rough material - can scrape your skin and cause infections

D. Machinery
   1. Understand the safety regulations that involve the guarding of moving parts
   2. Know what parts of the equipment are energized
   3. Use all safeguards that have been provided to protect people from machinery
   4. See that all guards and protectors are in place before you start to work
   5. If you must work nearer, turn the machine off and lock out the power
   6. Never work in, around, or near dangerous, unguarded openings without wearing a safety belt and a lifeline that is properly seamed

E. One-fifth of all injuries on the job involve moving parts, machinery, or tools

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Practical Application:

The students shall identify all major safeguards and protective devices on all covered machinery.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-A4) dealing with maintaining a clean and safe work environment

CNC-A3-HO
Follow Safe Operating Procedures for Hand and Machine Tools
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

- a. Identify and understand safe machine operating procedures; and,
- b. Demonstrate safe machine operation.

Module Outline:

- I. Identify and Understand Safe Machine Operating Procedures
  - A. Never make adjustments on a machine while it is running
    - 1. Keep guards in place at all times
    - 2. Discontinue power before servicing
    - 3. Keep body parts clear of moving machinery
    - 4. Beware of sharp edges and flying debris
    - 5. Secure work pieces to prevent slipping
    - 6. Never stand directly in line with blades or knives
    - 7. Avoid kickback
    - 8. Feed stack into machine correctly
  - B. Electrical safety
    - 1. Use only those electrical devices which have been approved by UL (Underwriters' Laboratories)
    - 2. Stand on dry surface when working on electrical equipment
    - 3. Replace defective cords or plugs on equipment
    - 4. Use only those tools that are in good condition
    - 5. Use only carbon dioxide or dry chemical fire extinguishers for control of electrical fires
    - 6. Obtain help when working on equipment that may become energized
  - C. Avoid horseplay and practical jokes
  - D. Keep work area clean.
- II. Demonstrate Safe Machine Operation
  - A. Good housekeeping
    - 1. Materials and equipment should be stacked straight and neat
    - 2. Keep aisles and walkways clear of tools, materials, and debris
    - 3. Dispose of scraps and rubbish daily
    - 4. Clean up spills
    - 5. Clean and store hand tools
  - B. Good techniques
    - 1. Always walk - do not run
    - 2. Never talk to or interrupt anyone who is operating a machine

   3. Never leave tools or pieces of stock lying on table surface of a machine being used
   4. When finished with a machine, turn power OFF and wait until blades or cutters have come to a complete stop before leaving
   5. Check stock for defects before machining
      a. Do not use a machine until you understand it thoroughly
      b. Do not jam or rush stock into machinery
      c. Keep guards in place
      d. Make sure power is OFF before working on or servicing
   6. Keep hands and fingers away from moving parts
   7. Don't try to run too small a piece through the machine
   8. Use a brush to clean the surface table
   9. Keep your eyes focused on what you are working on
   10. Never use an air hose to blow debris off yourself or other workers
   11. Report faulty machinery to your supervisor
   12. Make sure machinery is properly grounded
   13. Never leave a piece of machinery that is running unattended
   14. Make sure stack is solidly supported

C. Miscellaneous materials
   1. Molten metal - can splash and cause serious burns
   2. Chemicals - burn or irritate the skin or cause eye damage
   3. Broken glass - causes cuts, can get in the eyes
   4. Pointed objects - knives, screwdrivers, punches, staples can puncture the skin
   5. Rough material - can scrape your skin and cause infections

D. Machinery
   1. Understand the safety regulations that involve the guarding of moving parts
   2. Know what parts of the equipment are energized
   3. Use all safeguards that have been provided to protect people from machinery
   4. See that all guards and protectors are in place before you start to work
   5. If you must work nearer, turn the machine off and lock out the power
   6. Never work in, around, or near dangerous, unguarded openings without wearing a safety belt and a lifeline that is properly seamed

E. One-fifth of all injuries on the job involve moving parts, machinery, or tools

CNC-A3-LE
Follow Safe Operating Procedures for Hand and Machine Tools
Attachment 2: **MASTER** Laboratory Exercise

For this exercise, the instructor should allow the students to observe other workers at their stations. The students should look for only practices related to safety. Upon returning to class, the students and instructor should discuss what they saw.

NOTE TO ALL STUDENTS: Unless your instructor tells you otherwise, all questions are to be directed to the instructor only. Do **not** disturb you fellow workers at their stations. Such distractions, in and of themselves, pose risks!

Due to the nature of this exercise, no answer key is possible.

CNC-A3-LA

Follow Safe Operating Procedures for Hand and Machine Tools

Attachment 3: MASTER Laboratory Aid

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

Name______________________ Date____________

CNC-A3
Follow Safe Operating Procedures for Hand and Machine Tools
Self-Assessment

Circle the letter preceding the correct answer.

1. Barrier guards __________ the operator's access to the danger zone.
   A. Limit
   B. Prevent
   C. Stop the operator from entering maintenance area
   D. All of the above

2. Equipment grounding is accomplished by a separate wire which is colored:
   A. White.
   B. Black.
   C. Green.
   D. Red.

3. "Intrinsically safe" equipment is designed so that it cannot:
   A. Become damaged if dropped.
   B. Ignite materials nearby.
   C. Start its built-in alarm.
   D. Eliminate ground faults.

4. When making repairs on machinery the most important rule is to:
   A. Lock-out and tag-out.
   B. Report and document.
   C. Install barricades.
   D. Notify co-workers.

5. Safety guards would not be needed on machines if:
   A. Workers would be more careful.
   B. Machines had no moving parts.
   C. Safety rules were strictly enforced.
   D. Machines were better designed.

6. When you do maintenance work you are safer if you wear:
A. A good-luck charm bracelet.
B. Loose, comfortable clothing.
C. Tight-fitting clothing.
D. A narrow necktie.

7. Which of the following is not a pinch point?
A. Where a belt meets a pulley
B. Where a chain meets a sprocket
C. Where a belt passes close to a fixed object
D. Where a drill bit meets a work piece

8. After you have locked out the power to a machine, you should:
A. Make sure all moving parts have stopped.
B. Drain the hydraulic and pneumatic lines.
C. Block any parts that might move.
D. Do all of the above.

9. Debris should be cleared from machines using your:
A. Bare hands.
B. High pressure air hose.
C. Brush.
D. Neither, leave it for the next shift.

10. Which of the following statements is correct?
A. Understand the safety regulations that involve the guarding of moving parts.
B. Knowing what parts of the equipment are energized.
C. Use all safeguards to protect people.
D. All of the above.

11. You should begin work on a machine only after:
A. The supervisor tells you to.
B. You have read operating instructions and have been properly trained.
C. Warned other people.
D. All of the above.

12. Only authorized employees are permitted to install or remove locks or tags.
A. True
B. False

13. If a machine can't be locked or tagged a guard should be stationed at the controls.
    A. True
    B. False

14. It is permissible to talk to persons operating a piece of machinery.
    A. True
    B. False

15. Feed and extracting tools make it unnecessary for the operator to reach into the danger zone.
    A. True
    B. False

CNC-A3
Follow Safe Operating Procedures for Hand and Machine Tools
Self-Assessment Answer Key

1. A
2. C
3. B
4. A
5. B
6. C
7. D
8. D
9. C
10. D
11. B
12. A
13. A
14. B
15. A

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-A4

Subject: **Advanced CNC and CAM** **Time: 4 Hrs.**

Duty: **Practice Safety**
Task: Maintain a Clean and Safe Work Environment

Objective(s):

Upon completion of this unit the student will be able to:
a. Keep work areas clean;
b. Clean machine/hand tools when work is completed;
c. Put tools away when work is finished;
d. Keep isles clear of equipment and materials;
e. Perform preventive maintenance as required; and,
f. Understand chemical hazards and the use of Material Safety Data Sheets (MSDS).

Instructional Materials:

MASTER Handout (CNC-A4-HO)
MASTER Laboratory Exercise (CNC-A4-LE)
MASTER Laboratory Aid (CNC-A4-LA)
MASTER Self-Assessment

References:

Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition, Unit 1
OSHA General Industry Requirements, U. S. Government Printing Office, Latest Edition
Materials Safety Data Sheets

Student Preparation:

Students should have previously completed the following Technical Modules:
CNC-A1 "Follow Safety Manuals and All Safety Regulations/Requirements"
CNC-A2 "Use Protective Equipment"
CNC-A3 "Follow Safe Operating Procedures for Hand and Machine Tools"

Introduction:

Cleanliness is the first rule of safety. A clean neat work area helps prevent accidents. A cluttered area invites slips, trips, or falls. Clean up around your machine or equipment. If you are unable to do so, ask your supervisor for a helper to clean or stack material. Clean and store tools when you are finished and keep cords and hoses rolled up. Most accidents are caused by workers who do unsafe things. Learn to do your part by helping to create a safe work environment.

Presentation Outline:

I. Keep Work Areas Clean
    A. Discuss the associated dangers of the most common hazards of the work place
        1. Tripping/falling hazards caused by spills, loose objects, etc.
            a. Wipe up spills immediately
            b. Dispose of scrap material
            c. Do not wear loose clothing
            d. Never roll sleeves or pants
            e. keep shoe strings tied
            f. Position electrical cords and air hoses in safe areas
        2. Chemical hazards
            a. Inhalants
            b. Chemical burns
            c. Flammable liquids
            d. Explosives and explosive combinations
            e. Toxins
        3. Electrical hazards
        4. High-pressure hazards
    B. Discuss methods of avoiding and correcting common hazards
II. Clean Machine/Hand Tools When Work Is Completed
III. Put Tools Away When Work Is Finished
IV. Keep Isles Clear of Equipment and Materials
V. Perform Preventive Maintenance as Required
    A. Discuss that certain machines require extra precautions
    B. Discuss how general maintenance enhances general safety
VI. Understand the Use of Material Safety Data Sheets (MSDS)
    A. What chemicals have MSDS?
    B. Where are the MSDS kept?
    C. What information is on the MSDS?
        1. Product identification
            a. Specific product name and common name
            b. Precautionary labeling
            c. Safety equipment

    d. Precautionary label statements
    e. Storage color code
2. Hazardous components
3. Physical data
    a. Boiling point
    b. Vapor pressure
    c. Melting point
    d. Vapor density
    e. Specific gravity
    f. Evaporation rate
    g. Solubility in water
    h. Percentage of volatile components by volume
    I. Appearance & odor
4. Fire and explosion hazard data
    a. Flash point
    b. NFPA 704M rating
    c. Flammable limits (upper and lower)
    d. Fire extinguishing media
    e. Special fire-fighting procedures
    f. Toxic gases produced
5. Health hazard data
    a. Threshold limit value
    b. Permissible exposure limit
    c. Toxicity
    d. Carcinogenicity
    e. Effects of over-exposure
    f. Target organs (those most affected by exposure)
    g. Medical conditions aggravated by exposure
    h. Routes of entry
    I. Emergency and first-aid procedures
6. Reactivity data
    a. Stability
    b. Hazardous polymerization
    c. Conditions to avoid
    d. Incompatible materials
    e. Decomposition products
7. Spill and disposal procedures
    a. Procedures: spill or discharge
    b. Procedures: disposal
    c. EPA hazardous waste number
8. Protective equipment
    a. Ventilation
    b. Respiratory protection
    c. Eye/skin protection
9. Storage and handling precautions

        - a. Storage color code
        - b. Special precautions
- 10. Transportation data and additional information
    - a. Domestic transport
        - 1) DOT shipping name
        - 2) Hazard class
        - 3) UN/NA
        - 4) Labels
        - 5) Reportable quantity
    - b. International
        - 1) IMO shipping name
        - 2) Hazard class
        - 3) UN/NA
        - 4) Labels

Practical Application:

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-A5) dealing with lifting safely.

CNC-A4-HO
Maintain a Clean and Safe Work Environment
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:
- a. Keep work areas clean;
- b. Clean machine/hand tools when work is completed;
- c. Put tools away when work is finished;
- d. Keep isles clear of equipment and materials;
- e. Perform preventive maintenance as required; and,
- f. Understand chemical hazards and the use of Material Safety Data Sheets (MSDS).

Module Outline:

- I. Keep Work Areas Clean
    - A. Discuss the associated dangers of the most common hazards of the work place
        - 1. Tripping/falling hazards caused by spills, loose objects, etc.
            - a. Wipe up spills immediately
            - b. Dispose of scrap material
            - c. Do not wear loose clothing
            - d. Never roll sleeves or pants
            - e. keep shoe strings tied
            - f. Position electrical cords and air hoses in safe areas
        - 2. Chemical hazards
            - a. Inhalants
            - b. Chemical burns
            - c. Flammable liquids
            - d. Explosives and explosive combinations
            - e. Toxins
        - 3. Electrical hazards
        - 4. High-pressure hazards
    - B. Discuss methods of avoiding and correcting common hazards
- II. Clean Machine/Hand Tools When Work Is Completed
- III. Put Tools Away When Work Is Finished
- IV. Keep Isles Clear of Equipment and Materials
- V. Perform Preventive Maintenance as Required
    - A. Discuss that certain machines require extra precautions
    - B. Discuss how general maintenance enhances general safety
- VI. Understand the Use of Material Safety Data Sheets (MSDS)
    - A. What chemicals have MSDS?

B. Where are the MSDS kept?
C. What information is on the MSDS?
   1. Product identification
      a. Specific product name and common name
      b. Precautionary labeling
      c. Safety equipment
      d. Precautionary label statements
      e. Storage color code
   2. Hazardous components
   3. Physical data
      a. Boiling point
      b. Vapor pressure
      c. Melting point
      d. Vapor density
      e. Specific gravity
      f. Evaporation rate
      g. Solubility in water
      h. Percentage of volatile components by volume
      I. Appearance & odor
   4. Fire and explosion hazard data
      a. Flash point
      b. NFPA 704M rating
      c. Flammable limits (upper and lower)
      d. Fire extinguishing media
      e. Special fire-fighting procedures
      f. Toxic gases produced
   5. Health hazard data
      a. Threshold limit value
      b. Permissible exposure limit
      c. Toxicity
      d. Carcinogenicity
      e. Effects of over-exposure
      f. Target organs (those most affected by exposure)
      g. Medical conditions aggravated by exposure
      h. Routes of entry
      I. Emergency and first-aid procedures
   6. Reactivity data
      a. Stability
      b. Hazardous polymerization
      c. Conditions to avoid
      d. Incompatible materials
      e. Decomposition products
   7. Spill and disposal procedures
      a. Procedures: spill or discharge
      b. Procedures: disposal

   c. EPA hazardous waste number
8. Protective equipment
   a. Ventilation
   b. Respiratory protection
   c. Eye/skin protection
9. Storage and handling precautions
   a. Storage color code
   b. Special precautions
10. Transportation data and additional information
    a. Domestic transport
       1) DOT shipping name
       2) Hazard class
       3) UN/NA
       4) Labels
       5) Reportable quantity
    b. International
       1) IMO shipping name
       2) Hazard class
       3) UN/NA
       4) Labels

CNC-A4-LE
Maintain a Clean and Safe Work Environment
Attachment 2: MASTER Laboratory Exercise

The instructor will guide all students through part of the facility. Each student should write down as many safety hazards as are found. While this may appear to be an exact duplicate of CNC-A1, the purpose of this exercise is to determine how much more aware of safety and hazards the students have become.

Upon returning to class, the students and the instructor should discuss what the students observed on this tour. Each student should compare his answers to those from CNC-A1, noting any differences and the reasons for those differences.

Due to the nature of this laboratory exercise, no answer key is possible.

Safety Hazards

Type	Location	Description	Recommendations

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

Name________________________ Date_______________

CNC-A4
Maintain a Clean and Safe Work Environment
Self-Assessment:

Circle the letter preceding the correct answer.

1. A chemical label tells:
   - A. The carrier where to send the container
   - B. Only what the manufacture wants you to know
   - C. Only the maximum hazard
   - D. What a chemical's identity is

2. Labels are an important part of:
   - A. Your company's Hazard Communication Program
   - B. Right to know
   - C. Both a and b
   - D. Neither a nor b

3. On some labels, ___ represent the kind of hazards and ___ represent the degree of hazard.
   - A. Colors . . . numbers
   - B. Caution . . . danger
   - C. OSHA . . . MDS
   - D. All of the above

4. Before you start any jobs with chemicals, check the detailed hazard and safety information on the:
   - A. Supervisor's desk
   - B. Material Safety Data Sheet
   - C. Dock
   - D. Poison control center

5. Chemicals can enter the body by:
   - A. Swallowing
   - B. Inhaling
   - C. Skin contact
   - D. All of the above

6. The Control Measures Section of the MSDS covers the:
   - A. Protective equipment you might need
   - B. Exposure limits
   - C. Temperature limits
   - D. Spill and leak

7. Which of the following is *not* a good housekeeping rule?
   A. Always put tools in their proper place
   B. Dispose of waste material properly
   C. Sweep debris from machine with hands
   D. Wipe up spills immediately

8. Which of the following is a fire risk?
   A. Disposing of oily rags in tightly covered containers
   B. Storing flammables in electrical closets
   C. Keeping motors and machines free of dust and grease
   D. Keeping passages and fire exits clear

9. Before performing maintenance on a machine you should:
   A. Shut off power
   B. Warn other people
   C. Bring the machine to a zero energy state
   D. Lock-out power and the valves

10. If you have to work on a suspended load you should:
    A. Make sure you have clearance
    B. Place barricades around the hoist
    C. Watch out for pedestrians
    D. Set the load down first

11. Flammable liquids should be stored in:
    A. Open metal containers
    B. Sealed metal containers
    C. Open glass containers
    D. Sealed glass containers

12. During maintenance, the controls of a power-driven conveyor should be locked in the OFF position to prevent:
    A. Start-up
    B. Theft
    C. Damage
    D. Fire

13. When working aloft, you need:
    A. Guard rail clamps
    B. Safety toed shoes
    C. A safety harness
    D. A helper posted below

14. Scrap material should be:
    A. Stacked around the machine
    B. Cleared from the area
    C. Swept out in aisles
    D. All of the above

15. Danger that is part of the job is a:
    A. Built-in hazard
    B. Walk-on hazard
    C. Accident chain
    D. Hazardous duty
    E. Problem for the insurance company, not me

CNC-A4

Maintain a Clean and Safe Work Environment

Self-Assessment Answer Key

1. D

2. C

3. A

4. B

5. D

6. A

7. C

8. B

9. C

10. D

11. B

12. A

13. C

14. B

15. A

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-A5

Subject: Advanced CNC and CAM **Time:** 8 Hrs.

Duty: Practice Safety
Task: MSDS/Control Chemical Hazards

Objective(s):

Upon completion of this unit the student will be able to:

a. Define hazardous material;
b. Identify hazardous material;
c. Know the physical and chemical characteristics;
d. Describe storage, transportation, disposal of hazardous waste; and,
e. Explain material safety data sheets.

Instructional Materials:

MASTER Handout (CNC-A5-HO)
MASTER Laboratory Aid (CNC-A5-LA)
MASTER Self-Assessment

References:

OSHA General Industry Requirements, U. S. Government Printing Office, Latest Edition
Materials Safety Data Sheets for various chemicals

Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-A1	“Follow Safety Manuals and All Safety Regulations/Requirements”
CNC-A2	“Use Protective Equipment”
CNC-A3	“Follow Safe Operating Procedures for Hand and Machine Tools”
CNC-A4	"Maintain a Clean and Safe Work Environment"

Introduction:

Hazardous materials can cause immediate or long-term health problems if not managed properly. It is the responsibility of all persons involved with hazard waste to know the rules, the material, and how to handle the material properly.

Presentation Outline:

- I. Define Hazardous Materials According to the EPA
  - A. What makes a material hazardous?
    - 1. It is hazardous if it causes harm to people or environment
- II. Identify Hazardous Materials
  - A. Material Safety Data Sheets (MSDS)
    - 1. Companies that make and distribute hazardous substances must provide your company with a MSDS on hazardous material
    - 2. MSDS developed by OSHA
    - 3. MSDS is part of the Hazard Communication Standard or Right to Know regulation
    - 4. MSDS is an easy reference for information on hazardous substances
  - B. Information in MSDS
    - 1. What it is
    - 2. Who makes or sells it
    - 3. Where they are located
    - 4. Why it is hazardous
    - 5. How you can be exposed to the hazard
    - 6. Conditions that could increase the hazard
    - 7. How to handle the substance safely
    - 8. Protection to use while working with it
    - 9. What to do if exposed
    - 10. What to do if there is a spill or emergency
- III. Know the Chemical and Physical Characteristics
  - A. Corrosive
    - 1. Burns skin or eyes on contact
  - B. Explosive
  - C. Flammable
    - 1. Catches fire easily
  - D. Radioactive
  - E. Reactive
    - 1. Burns, explodes
    - 2. Releases toxic vapors
  - F. Toxic
    - 1. Causes illness or possibly death
- IV. Describe Storage, Transportation, Disposal
  - A. Resource Conservation and Recovery Act (RCRA)
    - 1. Designed to reduce hazards of waste by tracking and regulating the substance
    - 2. Method used is called from cradle (creation) to grave (disposal)

    3. Tells what hazards are and how to keep track of them
    4. Sets up rules for handling wastes
    5. Provides strict documentation system to track them

B. Your employer may have to report to the Environmental Protection Agency (EPA) on how the company is meeting the RCRA responsibilities

C. The law requires companies that treat, store, or dispose of hazardous wastes to:
    1. Must have a permit
    2. Identify and analyze new hazardous waste
    3. Provide a secure facility that keeps unauthorized people out
    4. Inspect the facility regularly
    5. Have a contingency plan for fire, explosion, and spills
    6. Practice emergency response for fire, explosion, spills
    7. Provide proper protective clothing and equipment
    8. Maintain EPA-required records

Practical Application:

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-B1) dealing with performing basic arithmetic functions.

CNC-A5-HO
MSDS/Control Chemical Hazards
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Define hazardous material;
b. Identify hazardous material;
c. Know the physical and chemical characteristics;
d. Describe storage, transportation, disposal of hazardous waste; and,
e. Explain material safety data sheets.

Module Outline:

I. Define Hazardous Materials According to the EPA
    A. What makes a material hazardous?
        1. It is hazardous if it causes harm to people or environment
II. Identify Hazardous Materials
    A. Material Safety Data Sheets (MSDS)
        1. Companies that make and distribute hazardous substances must provide your company with a MSDS on hazardous material
        2. MSDS developed by OSHA
        3. MSDS is part of the Hazard Communication Standard or Right to Know regulation
        4. MSDS is an easy reference for information on hazardous substances
    B. Information in MSDS
        1. What it is
        2. Who makes or sells it
        3. Where they are located
        4. Why it is hazardous
        5. How you can be exposed to the hazard
        6. Conditions that could increase the hazard
        7. How to handle the substance safely
        8. Protection to use while working with it
        9. What to do if exposed
        10. What to do if there is a spill or emergency
III. Know the Chemical and Physical Characteristics
    A. Corrosive
        1. Burns skin or eyes on contact
    B. Explosive
    C. Flammable

1. Catches fire easily

D. Radioactive

E. Reactive
   1. Burns, explodes
   2. Releases toxic vapors

F. Toxic
   1. Causes illness or possibly death

IV. Describe Storage, Transportation, Disposal

A. Resource Conservation and Recovery Act (RCRA)
   1. Designed to reduce hazards of waste by tracking and regulating the substance
   2. Method used is called from cradle (creation) to grave (disposal)
   3. Tells what hazards are and how to keep track of them
   4. Sets up rules for handling wastes
   5. Provides strict documentation system to track them

B. Your employer may have to report to the Environmental Protection Agency (EPA) on how the company is meeting the RCRA responsibilities

C. The law requires companies that treat, store, or dispose of hazardous wastes to:
   1. Must have a permit
   2. Identify and analyze new hazardous waste
   3. Provide a secure facility that keeps unauthorized people out
   4. Inspect the facility regularly
   5. Have a contingency plan for fire, explosion, and spills
   6. Practice emergency response for fire, explosion, spills
   7. Provide proper protective clothing and equipment
   8. Maintain EPA-required records

CNC-A5-LA
MSDS/Control Chemical Hazards
Attachment 2: MASTER Laboratory Aid

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

Name__________________________ Date_______________

CNC-A5
MSDS/Control Chemical Hazards
Self-Assessment

Circle the letter preceding the correct answer.

1. The law requires companies that treat, store, or dispose of hazardous wastes to _________.
   a. Have a permit
   b. Give notice before dumping
   c. Have OSHA personnel on site at all times
   d. All of the above

2. Your employer may have to report to the ________ on how the company is meeting the RCRA responsibility.
   a. OSHA
   b. EPA
   c. RCRA
   d. Local authorities

3. The EPA requires paperwork that tracks hazardous waste from ________ to ___________.
   a. Company to company
   b. State to state
   c. Cradle to grave
   d. Manufacturer to company

4. The key pieces of information in the manifest are ___________.
   a. Manifest document number
   b. Name, address, phone numbers, EPA ID number of generator
   c. Description of the hazardous waste
   d. All of the above

5. Who must sign the manifest and keep a copy?
   a. Only the manufacture
   b. Only the shipper
   c. Only those who dispose of the waste
   d. Everyone who handles the waste

6. A material safety data sheet tells you the chemical's __________.
   a. Market value
   b. Color
   c. Physical and chemical characteristics
   d. All of the above

7. If properly wrapped, hazardous waste ____________________.
   a. May be disposed of at public dumps
   b. Must be disposed of according to the EPA guidelines
   c. Dumped on private property
   d. All of the above

8. MSDS stands for _____________.
   a. Material safety data sheet
   b. Military secret dumping site
   c. Mine safety division storage
   d. Material safe disposal site

9. OSHA developed the MSDS as part of _____________.
   a. Hazard communication standard
   b. Right-to-know regulations
   c. Both A & B
   d. Neither A nor B

10. The _____________ part of the label can either indicate a specific hazard or what personal protective equipment should be used.
   a. White
   b. Red
   c. Triangle
   d. Cross-hairs

CNC-A5
MSDS/Control Chemical Hazards
Self-Assessment Answer Key

1. a
2. b
3. c
4. d
5. d
6. c
7. b
8. a
9. c
10. a

CNC MACHINIST .... programs, edits, sets up, and operates CNC lathes, mills and grinders to perform machining operations necessary to produce workpieces to referenced engineering standards.

Duties		Tasks												
A	Practice Safety	A-1 Follow safety manuals and all safety regulations/ requirements	A-2 Use protective equipment	A-3 Follow safe operating procedures for hand and machine tools	A-4 Maintain a clean and safe work environment	A-5 MSDS/ control chemical hazards								
B	Apply Mathematical Concepts	B-1 Perform basic arithmetic functions	B-2 Convert fractions/ decimals	B-3 Convert Metric/ English measurements	B-4 Perform basic algebraic operations	B-5 Use practical geometry	B-6 Understand basic trigonometry	B-7 Calculate speeds and feeds for machining	B-8 Use coordinate systems					
C	Interpret Engineering Drawings and Control Documents	C-1 Identify basic layout of drawings	C-2 Identify basic types of drawings	C-3 Review blueprint notes and dimensions	C-4 List the purpose of each type of drawing	C-5 Verify drawing elements	C-6 Practice Geometric Dimensioning and Tolerancing (GD&T)	C-7 Analyze bill of materials (BOM)	C-8 Describe the relationship of engineering drawings to planning	C-9 Understand and use quality systems	C-10 Verify standard requirements			
D	Recognize Different Manufacturing Materials and Processes	D-1 Identify materials with desired properties	D-2 Identify materials and processes to produce a part	D-3 Describe the heat treating process	D-4 Test metal samples for hardness	D-5 Understand welding operations								
E	Measure/ Inspect	E-1 Understand metrology terms	E-2 Select measurement tools	E-3 Measure with hand held instruments	E-4 Eliminate measurement variables	E-5 Measure/ inspect using surface plate and accessories	E-6 Inspect using stationary equipment							
F	Perform Conventional Machining	F-1 Prepare and plan for machining operations	F-2 Use hand tools	F-3 Operate power saws	F-4 Operate drill presses	F-5 Operate vertical milling machines	F-6 Operate horizontal milling machines	F-7 Operate metal cutting lathes	F-8 Operate grinding/ abrasive machines					
G	Perform Advanced Machining	G-1 Understand CNC basics	G-2 Program CNC machines	G-3 Operate CNC machining centers (mills)	G-4 Operate CNC turning centers (lathes)									
H	Use Verification and Communication Systems	H-1 Use personal computer	H-2 Use various operating systems	H-3 Use computer communications systems	H-4 Use verification systems	H-5 Use the Internet								
I	Program Using CAM System	I-1 Understand CAD/ CAM programs	I-2 Manipulate CAD functions	I-3 Process simple tool-path data	I-4 Create advanced surface models	I-5 Process complex tool-path functions								

CNC [illegible]
[illegible]

CNC-B1

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-B1

Subject: **Advanced CNC and CAM** **Time: 1 Hr.**

Duty: **Apply Mathematical Concepts**
Task: Perform Basic Arithmetic Functions

Objective(s):

Upon completion of this unit the student will be able to:

a. Add, subtract, multiply, and divide whole numbers;
b. Add, subtract, multiply, and divide fractions; and,
c. Add, subtract, multiply, and divide decimals.

Instructional Materials:

MASTER Handout (CNC-B1-HO)
MASTER Laboratory Aid (CNC-B1-LA)
MASTER Self-Assessment

References:

Student's Shop Reference Handbook, Industrial Press, Latest Edition, Unit on Mathematics
Mathematics for Machine Technology, R. D. Smith, Delmar Publishers, Inc., Latest Edition, Units 1-12

Student Preparation:

Introduction:

Mathematics is called the "Queen of Sciences" for a definite reason. In the modern world, almost nothing can be done without it. Fundamental to success in all mathematics is a thorough and complete understanding of the four basic functions of arithmetic: Addition, Subtraction, Multiplication, and Division. Technicians must perform all functions of arithmetic on a daily basis and with complete confidence. This lesson is designed to dust off all your old memories and to permit you to see that solid base of arithmetic which you must surely have to progress.

Presentation Outline:

- I. Add, Subtract, Multiply, and Divide Whole Numbers
  - A. Addition of whole numbers
  - B. Subtraction of whole numbers
  - C. Multiplication of whole numbers
  - D. Division of whole numbers
  - E. Hierarchy of operations
- II. Add, Subtract, Multiply, and Divide Fractions
  - A. Common operations
    - 1. Least common denominator
    - 2. Factoring for reduction
    - 3. Improper fractions
    - 4. Mixed numbers
  - B. Addition
  - C. Subtraction
  - D. Multiplication
  - E. Division
- III. Add, Subtract, Multiply, and Divide Decimals
  - A. Aligning the decimal (addition and subtraction)
  - B. Moving the decimal
    - 1. In division, move the decimal to the right until it is eliminated in the divisor. Move the decimal the same number of places to the right in the dividend.
    - 2. In multiplication, count the total number of decimals places in the two numbers being multiplied. Beginning in the product at the *right-most digit,* count off the same number of places and place the decimal.

Practical Application:

The students shall demonstrate a working knowledge of the four basic operations of arithmetic and an ability to reduce fractions.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-B2) dealing with the conversion of fractions and decimals.

CNC-B1-HO
Perform Basic Arithmetic Functions
Attachment 1: MASTER Handout

Objective(s):

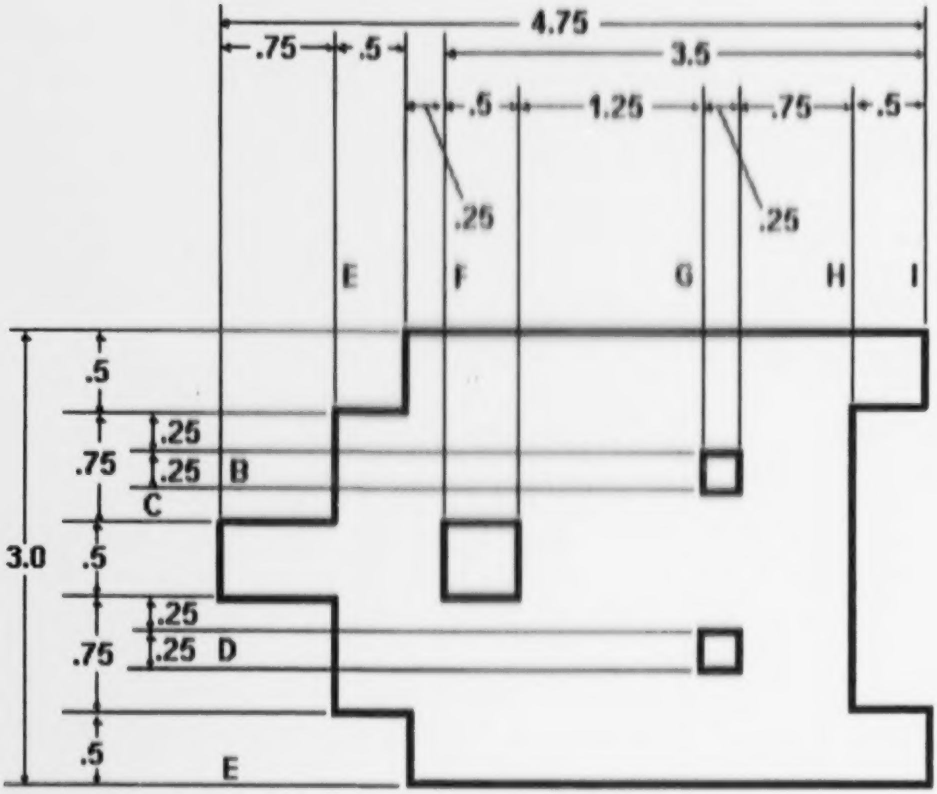
Upon completion of this unit the student will be able to:

a. Add, subtract, multiply, and divide whole numbers;
b. Add, subtract, multiply, and divide fractions; and,
c. Add, subtract, multiply, and divide decimals.

Module Outline:

I. Add, Subtract, Multiply, and Divide Whole Numbers
    A. Addition of whole numbers
    B. Subtraction of whole numbers
    C. Multiplication of whole numbers
    D. Division of whole numbers
    E. Hierarchy of operations
II. Add, Subtract, Multiply, and Divide Fractions
    A. Common operations
        1. Least common denominator
        2. Factoring for reduction
        3. Improper fractions
        4. Mixed numbers
    B. Addition
    C. Subtraction
    D. Multiplication
    E. Division
III. Add, Subtract, Multiply, and Divide Decimals
    A. Aligning the decimal (addition and subtraction)
    B. Moving the decimal
        1. In division, move the decimal to the right until it is eliminated in the divisor. Move the decimal the same number of places to the right in the dividend.
        2. In multiplication, count the total number of decimals places in the two numbers being multiplied. Beginning in the product at the *right-most digit,* count off the same number of places and place the decimal.

CNC-B1-LA
Perform Basic Arithmetic Functions
Attachment 2: MASTER Laboratory Aid


4.75
.75
.5
3.5
.5
1.25
.75
.5
.25
.25
E
F
G
H
I
.5
.25
.75
.25
B
C
3.0
.5
.25
.75
.25
D
.5
E

Name______________________________ Date________________

CNC-B1
Perform Basic Arithmetic Functions
Self-Assessment

Show all work.

Reduce the following fractions:

1. 4/64 ______________________________
2. 6/4 ______________________________
3. 6/16 ______________________________
4. 12/32 ______________________________
5. 9/16 ______________________________

Perform the indicated operations:

6. 3.25 + 2.375 = ______________________________
7. 15/32 + 1/4 = ______________________________
8. 15/32 - 1/4 = ______________________________
9. 9/64 + 9/32 = ______________________________
10. 1/4 x 3/4 = ______________________________
11. 1/4 ÷ 3/4 = ______________________________
12. 0.625 x 1/4 = ______________________________
13. 0.625 + 1.125 = ______________________________
14. 1.125 - 0.75 = ______________________________
15. 1.25/1.5 = ______________________________

For Questions 16 through 25, use the dimensional notations on the drawing.

16. What is the distance between Line A and Line B? ________________

17. What is the distance between Line B and Line C? ________________

18. What is the distance between Line B and Line D? ________________

19. What is the distance between Line C and Line E? ________________

20. What is the distance between Line C and Line D? ________________

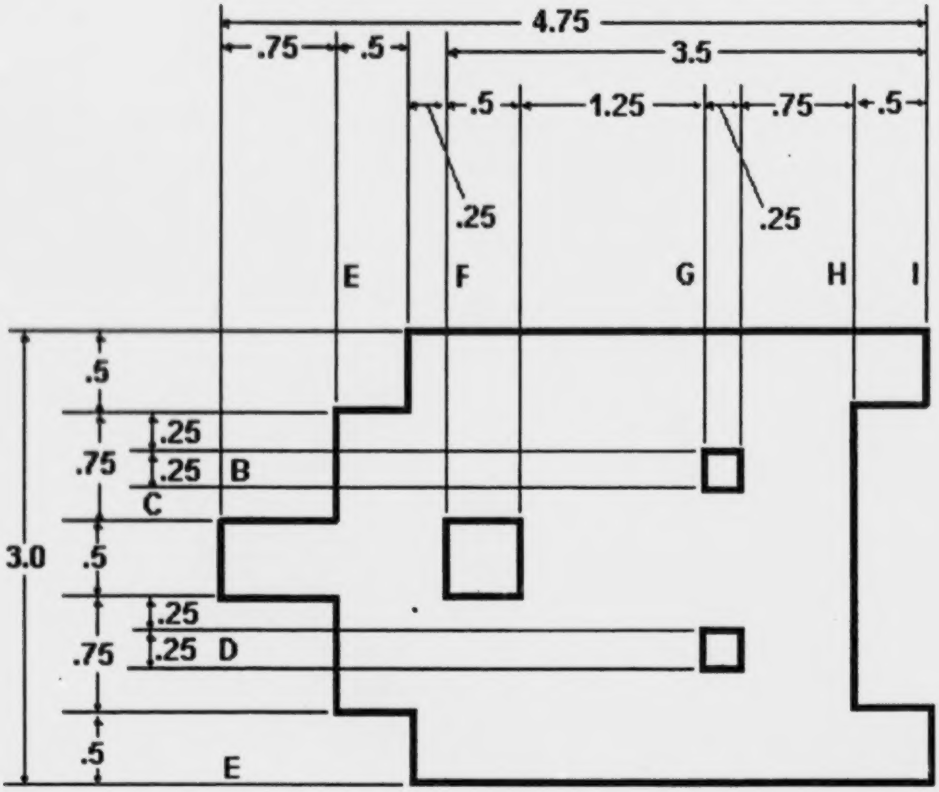
21. What is the distance between Line E and Line F? ________________

22. What is the distance between Line F and Line G? ________________

23. What is the distance between Line F and Line I? ________________

24. What is the distance between Line G and Line H? ________________

25. What is the distance between Line I and Line E? ________________


4.75
.75
.5
3.5
.5
1.25
.75
.5
.25
.25
E
F
G
H
I
.5
.25
.75
.25
B
C
3.0
.5
.25
.75
.25
D
.5
E

CNC-B1
Perform Basic Arithmetic Functions
Self-Assessment Answer Key

1. 1/16
2. 1 ½
3. 3/8
4. 3/8
5. 9/16
6. 5.625
7. 23/32
8. 7/32
9. 27/64
10. 3/16
11. 1/3
12. 0.156
13. 1.75
14. 0.375
15. 0.833
16. 0.75
17. 0.25
18. 1.25
19. 1.75
20. 1.0
21. 0.75
22. 1.75
23. 3.25
24. 1.0
25. 4.0

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-B2

Subject: **Advanced CNC and CAM** **Time: 2 Hrs.**

Duty: **Apply Mathematical Concepts**
Task: Convert Fractions/Decimals

Objective(s):

Upon completion of this unit the student will be able to:

a. Write fractions as decimals;
b. Write decimals as fractions; and,
c. Use fractions and decimals interchangeably.

Instructional Materials:

MASTER Handout (CNC-B2-HO)
MASTER Self-Assessment

References:

Student's Shop Reference Handbook, Industrial Press, Latest Edition, Unit on Mathematics

Mathematics for Machine Technology, R. D. Smith, Delmar Publishers, Inc., Latest Edition, Unit 8: Rounding Decimal Fractions and Equivalent Decimal and Common Fractions

Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-B1 "Perform Basic Arithmetic Functions"

Introduction:

Unfortunately, nothing is standard. One tool has decimal fractions on its indicators; the next has increments of 1/64th inch. One drafter prefers common fractions; the next marks off everything in decimals. It's enough to make a grown technician cry! Of course, on the shop floor, you cannot carry around a beach towel to catch all the tears. All this confusion leads to only one conclusion: The successful technician easily converts decimal fractions to common fractions, and *vice versa*.

Presentation Outline:

I. Write Fractions as Decimals
  A. Understand and be able to use equivalent fractions
  B. Write fractions in lowest terms
  C. Understand improper fractions and mixed numbers
  D. Be able to write fractions as decimals by performing the indicated division

II. Write Decimals as Fractions
  A. Understand the place value in decimals
  B. Understand how to find the fraction or mixed number equivalent of decimals by writing the digits over the place value and reducing this to the lowest terms

III. Use Fractions and Decimals Interchangeably
  A. Understand how fractions and decimals can be used interchangeably to represent the same value
  B. Be able to determine the best representation, fraction or decimal, for a given industrial problem

IV. Common Technical Conversions
  A. These are the six most important conversions from denominative fractions to decimal fractions
    1. 1/64 is *about* .016 (sixteen thousandths)
    2. 1/32 is *about* .031 (thirty-one thousandths)
    3. 1/16 is *about* .062 (sixty-two thousandths)
    4. 1/8 is .125 (one hundred twenty-five thousandths)
    5. 1/4 is .250 (two hundred fifty thousandths)
    6. 1/2 is .500 (five hundred thousandths)
  B. The trick to quickly converting these fractions is to think of them just like they were building blocks. For example, how much is 11/16 inch in thousandths? 11/16 is actually 1/2 + 1/8 + 1/16, so it is also .500 + .125 + .062, or .687.
  C. If you, the technician, will learn the six basic conversions listed above, then you will have won half the battle of fractional conversions.
  D. It is also helpful to think in thousandths. Don't think of .5 as one-half or five tenths, think of it as 500 thousandths. Thinking this way will automatically align the decimal places for you and allow you to quickly add and subtract measurements.
  E. By the same token, it is easier to think in 64ths than it is to carry around all those fractions in your head. Converting fractions can cause errors because it is another step. Since the assumed standard of tolerance in binary fractions is 1/64 inch, *think that way.* One-half becomes 32/64; one-eighth, 8/64. The arithmetic almost does itself when all the fractions in your head have common denominators.

Practical Application:

Students will be able to convert fractions and decimals as needed to conduct operations encountered in the manufacturing industry, such as interpreting denominative blueprints for production on decimal machines and choosing the proper drill bits for decimal holes. The student should understand that this is a fairly common occurrence in the shop.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-B3) dealing with the conversion of Metric/English measurements.

CNC-B2-HO
Convert Fractions/Decimals
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:
- a. Write fractions as decimals;
- b. Write decimals as fractions; and,
- c. Use fractions and decimals interchangeably.

Module Outline:

- I. Write Fractions as Decimals
  - A. Understand and be able to use equivalent fractions
  - B. Write fractions in lowest terms
  - C. Understand improper fractions and mixed numbers
  - D. Be able to write fractions as decimals by performing the indicated division
- II. Write Decimals as Fractions
  - A. Understand the place value in decimals
  - B. Understand how to find the fraction or mixed number equivalent of decimals by writing the digits over the place value and reducing this to the lowest terms
- III. Use Fractions and Decimals Interchangeably
  - A. Understand how fractions and decimals can be used interchangeably to represent the same value
  - B. Be able to determine the best representation, fraction or decimal, for a given industrial problem
- IV. Common Technical Conversions
  - A. These are the six most important conversions from denominative fractions to decimal fractions
    1. 1/64 is *about* .016 (sixteen thousandths)
    2. 1/32 is *about* .031 (thirty-one thousandths)
    3. 1/16 is *about* .062 (sixty-two thousandths)
    4. 1/8 is .125 (one hundred twenty-five thousandths)
    5. 1/4 is .250 (two hundred fifty thousandths)
    6. 1/2 is .500 (five hundred thousandths)
  - B. The trick to quickly converting these fractions is to think of them just like they were building blocks. For example, how much is 11/16 inch in thousandths? 11/16 is actually 1/2 + 1/8 + 1/16, so it is also .500 + .125 + .062, or .687.
  - C. If you, the technician, will learn the six basic conversions listed above, then you will have won half the battle of fractional conversions.

D. It is also helpful to think in thousandths. Don't think of .5 as one-half or five tenths, think of it as 500 thousandths. Thinking this way will automatically align the decimal places for you and allow you to quickly add and subtract measurements.

E. By the same token, it is easier to think in 64ths than it is to carry around all those fractions in your head. Converting fractions can cause errors because it is another step. Since the assumed standard of tolerance in binary fractions is 1/64 inch, *think that way*. One-half becomes 32/64; one-eighth, 8/64. The arithmetic almost does itself when all the fractions in your head have common denominators.

Name________________________ Date______________

CNC-B2
Convert Fractions/Decimals
Self-Assessment

Convert the following to decimal fractions:

1. 1/8 ________________________
2. 1/16 ________________________
3. 1/4 ________________________
4. 1/32 ________________________
5. 1/64 ________________________

Reduce the following fractions to the lowest denominator:

6. 4/16 ________________________
7. 12/32 ________________________
8. 20/64 ________________________
9. 4/8 ________________________
10. 9/16 ________________________

Using the "Building Blocks," give the decimal equivalents of the following:

11. 13/16 ________________________
12. 35/64 ________________________
13. 5/16 ________________________
14. 5/32 ________________________
15. 9/32 ________________________

Using the Drill Bit Table below, choose the best bit to drill the designated holes.

Drill Bits Available:

1/64	1/32	1/16	3/32	7/64	1/8
5/32	11/64	1/4	1/2	5/8	13/64

Holes to be drilled:

16. .125" ____________________

17. .5" ____________________

18. .875" ____________________

19. .0625" ____________________

20. .094" ____________________

21. .250" ____________________

22. .625" ____________________

CNC-B2
Convert Fractions/Decimals
Self-Assessment Answer Key

1. .125
2. .062
3. .25
4. .031
5. .016
6. 1/4
7. 3/8
8. 5/16
9. 1/2
10. 9/16 (This fraction is unreduceable.)
11. .5 + .25 + .062 = .812
12. .5 + .031 +.016 = .547
13. .25 + .062 = .312
14. .125 + .031 = .156
15. .25 + .031 = .56
16. 1/8
17. 1/2
18. 5/8
19. 1/16
20. 3/32
21. 1/4
22. 3/8

CNC-B3

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-B3

Subject: Advanced CNC and CAM **Time:** 2 Hrs.

Duty: Apply Mathematical Concepts
Task: Convert Metric/English (Customary or English) Measurements

Objective(s):

Upon completion of this unit the student will be able to:

a. Make inch, foot, and yard (English) measurements using rulers, calipers, and height gages;
b. Make millimeter, centimeter, meter (metric) measurements using metric rulers, calipers, and height gages; and,
c. Use English and metric measurements interchangeably.

Instructional Materials:

Rulers, calipers, and height gages marked in both English and metric units of measurement
Table of English/metric conversions (provided on Self-Assessment)
Calculators for students
MASTER Handout (CNC-B3-HO)
MASTER Self-Assessment

References:

Student's Shop Reference Handbook, Industrial Press, Latest Edition, Unit on Mathematics
Mathematics for Machine Technology, R. D. Smith, Delmar Publishers, Inc., Latest Edition, Section 2, Linear Measurement: English and Metric

Student Preparation:

Students should have previously completed the following Technical Modules:
CNC-B1 "Perform Basic Arithmetic Functions"

Introduction:

An experienced machinist will often have to take the time to plan his/her own work as well as the work of others on occasion so that manufacturing operations can be performed in the most efficient manner. Understanding English and metric measurements of length and being able to use the two units of measurement interchangeably will help in accurate planning of work and in the preparation of machines and tools which will yield increased production, better quality, less scrap/rework, and more time to concentrate on manufacturing quality and productivity improvements. Many situations a machinist will face require basic understanding of both units of measure as applied to the industrial setting. To be better machinists, and incidentally better employees, good technicians will understand and be able to use English and metric measurements of length interchangeably.

Presentation Outline:

I. Make Inch, Foot, and Yard (English) Measurements Using Rulers, Calipers, and Height Gages
  A. Know the units of length, their symbols and relationships
  B. Be able to convert from one unit of length to another
  C. Be able to choose the degree of accuracy desired when making length measurements
  D. Be able to measure to the nearest 1/64 inch using rulers, and to the nearest .001" using calipers and height gages
II. Write Millimeter, Centimeter, and Meter (Metric) Measurements Using Metric Rulers, Calipers, and Height Gages
  A. Know the metric units of length, their symbols and relationships
  B. Be able to convert from one metric unit of length to another
  C. Be able to choose the degree of accuracy desired when making metric unit of length measurements
  D. Be able to measure to the nearest centimeter or millimeter using metric rulers, calipers, and height gages
III. Convert Metric/English Units of Length
  A. Know how to convert metric to English units using a conversion factors table
  B. Know how to convert English units to metric units using a conversion factors table

Practical Application:

Students will be able to make English and metric length measurements, and be able to convert the measurements using a Metric-English Linear Equivalents (Conversion Factors) Table as needed to conduct operations encountered in the manufacturing industry.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-B4) dealing with performing basic algebraic operations.

CNC-B3-HO
Convert Metric/English (Customary or English) Measurements
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Make inch, foot, and yard (English) measurements using rulers, calipers, and height gages;
b. Make millimeter, centimeter, meter (metric) measurements using metric rulers, calipers, and height gages; and,
c. Use English and metric measurements interchangeably.

Module Outline:

I. Make Inch, Foot, and Yard (English) Measurements Using Rulers, Calipers, and Height Gages
  A. Know the units of length, their symbols and relationships
  B. Be able to convert from one unit of length to another
  C. Be able to choose the degree of accuracy desired when making length measurements
  D. Be able to measure to the nearest 1/64 inch using rulers, and to the nearest .001" using calipers and height gages
II. Write Millimeter, Centimeter, and Meter (Metric) Measurements Using Metric Rulers, Calipers, and Height Gages
  A. Know the metric units of length, their symbols and relationships
  B. Be able to convert from one metric unit of length to another
  C. Be able to choose the degree of accuracy desired when making metric unit of length measurements
  D. Be able to measure to the nearest centimeter or millimeter using metric rulers, calipers, and height gages
III. Convert Metric/English Units of Length
  A. Know how to convert metric to English units using a conversion factors table
  B. Know how to convert English units to metric units using a conversion factors table

Name_____________________________ Date_______________

CNC-B3
Convert Metric/English Measurements
Self-Assessment

Circle the letter preceding the correct answer.

Convert the following metric measurements to English equivalents using the following conversion factors:

1 millimeter (mm) = 0.03937 inch (in)
1 centimeter (cm) = 0.3937 inch (in)
1 meter (m) = 39.37 inches (in)
1 meter (m) = 3.2808 feet (ft)

1. 5 mm = _____ in
    a. 0.19685
    b. 1.565
    c. 0.6875
    d. 2.675

2. 2 cm = _____ in
    a. 0.875
    b. 0.7874
    c. 6875
    d. 2.175

3. 2 m = _____ ft
    a. 5
    b. 6.958
    c. 6.5616
    d. 8

4. 20 m = _____ ft.
    a. 45
    b. 65.616
    c. 40
    d. 25

5. 20 cm = _____ in
    a. 2.0
    b. 1.5
    c. 7.874
    d. 3.0

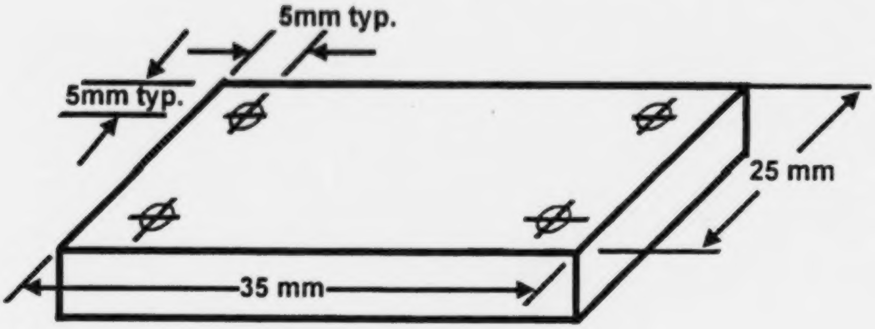
Write the following English units as metric units using the following conversion factors:

1 inch (in) = 25.4 millimeters (mm)
1 inch (in) = 2.54 centimeters (cm)
1 foot (ft) = 0.3048 meter (m)

6. 2 in = _____ mm
   - a. 50.9
   - b. 65
   - c. 79
   - d. 19

7. 2 in = _____. cm
   - a. 15
   - b. 24
   - c. 5.09
   - d. 150

8. 10 ft = _____ m
   - a. 3.048
   - b. 38
   - c. 4
   - d. 1.4


5mm typ.
5mm typ.
25 mm
35 mm

9. Given the above drawing and a milling machine graduated in thousands of an inch, how would you calculate the hole locations to be able to make this part?

CNC-B3
Convert Metric/English Measurements
Self-Assessment Answer Key

1. A
2. B
3. C
4. B
5. C
6. A
7. C
8. A

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-B4

Subject: **Advanced CNC and CAM** **Time: 8 Hrs.**

Duty: **Apply Mathematical Concepts**
Task: Perform Basic Algebraic Operations

Objective(s):

Upon completion of this unit the student will be able to:
a. Understand basic algebraic symbols and expressions; and,
b. Use equations to solve problems.

Instructional Materials:

Calculators for Students
MASTER Handout (CNC-B4-HO)
MASTER Self-Assessment

References:

Mathematics for Machine Technology, R. D. Smith, Delmar Publishing, Latest Edition

Student Preparation:

Students should have previously completed the following Technical Modules:
CNC-B1 "Perform Basic Arithmetic Functions"

Introduction:

Algebra is critical in the workplace because technicians frequently encounter situations that include unknown quantities. The purpose of algebra is to provide a means of mathematically describing any situation so that those unknown quantities can be certainly deduced. In other words, algebra is *not* a set series of formulas; rather, it is a *way of thinking about numbers*. As a technician, you will daily take rods and bars of metal and form them into sometimes intricate parts on the lathe or the milling machine. Algebra is the lathe of mathematics—with its processes, you can manipulate numbers as easily as you work bronze or aluminum. Look past the fancy names that have been stuck on the processes and rules of algebra and look at what they *say and do* in common language. Many experienced machinists do algebra every day, *in their heads*, and never even realize what they are doing!

Presentation Outline:

I. Understand Basic Algebraic Symbols and Expressions
   A. Symbols
      1. Addition "+"
      2. Subtraction "-"
      3. Multiplication "·"; "x", and parentheses
      4. Division "÷" and "/"
      5. Exponents are generally limited to the term "square" in linear measurements. This is the "^{2}" notation.
   B. Expressions
      1. Sum: the total amount resulting from addition
      2. Difference: the remaining amount resulting from subtraction
      3. Product: the total amount resulting from multiplication
      4. Exponent: a superscript which indicates the number of times a quantity is multiplied by itself
      5. Quotient: the amount resulting from division

II. Use a Few Easy-to-Remember Rules to Solve Equations
   A. *P*lease *E*xcuse *My D*ear *A*unt *S*ue indicates the order in which equations are solved. Each letter shows one of the algebraic notations or functions: Parentheses, Exponents, Multiply, Divide, Add, Subtract.
      1. In the expression $(x - y)^2 + 2x^2 - y^2$, the *p*arentheses, which must be worked first, indicate that y must be subtracted from x. Since we don't know what x and y are, we can't do that, and must move on.
      2. The next step is to square the term $(x - y)$, as indicated by the *e*xponent. This gives us $x^2 - 2xy + y^2 + 2x^2 - y^2$.
      3. There is no operable *m*ultiplication or *d*ivision in this expression, so we move on.
      4. Grouping all the like terms to make seeing the answer easier, we have $x^2 + 2x^2 + y^2 - y^2 - 2xy$.
      5. *A*dding, we now have $3x^2 + y^2 - y^2 - 2xy$.
      6. *S*ubtracting, which is the final step, renders $3x^2 - 2xy$.
   B. *FOIL* gives the order in which you multiply the terms in expressions. Let us go back to squaring (multiplying by itself) $(x - y)$ from the expression above.
      1. *F*irst terms first, so, in $(x - y)(x - y)$, multiply the two x's first. This give us x^2.
      2. *O*utside terms come next, so multiply the first x by the second y. This gives us $x^2 - xy$.
      3. *I*nside terms come next, so multiply the first y by the second x. This gives us $x^2 - xy - xy$.

4. *L*ast terms are last, so multiply the two y's. This gives us a complete (if complex) $x^2 - xy - xy + y^2$.
5. Simplifying gives us the expression $x^2 - 2xy + y^2$.

C. Thinking about algebra can be daunting to almost anybody, but once you see that algebra is just juggling done with numbers and with a lot of two-dollar words stuck all over it, algebra becomes rather simple. Remember, algebra is just taking the four basic mathematic operations (addition, subtraction, multiplication, and division) and using them to find out something that you didn't know to start with.

D. Word problems are what you will encounter every day in the shop. Someone will tell you to get so much material and make so many parts from it. As you progress in skill, they will tell you to get such-and-such material and make so many parts from it. Your mastery of basic algebra will make these problems easy to solve.

Practical Application:

Students will be able to perform basic algebraic operations as needed to solve problems and to conduct operations encountered in the manufacturing industry. Taper calculations, thread calculations, and rpm calculations are all based on algebra.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-B5) dealing with practical geometry.

CNC-B4-HO
Perform Basic Algebraic Operations
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Understand basic algebraic symbols and expressions; and,
b. Use equations to solve problems.

Module Outline:

I. Understand Basic Algebraic Symbols and Expressions
   - A. Symbols
      - 1. Addition “+”
      - 2. Subtraction “-”
      - 3. Multiplication “·”; “x”, and parentheses
      - 4. Division “÷” and “/”
      - 5. Exponents are generally limited to the term “square” in linear measurements. This is the “^{2}“ notation.
   - B. Expressions
      - 1. Sum: the total amount resulting from addition
      - 2. Difference: the remaining amount resulting from subtraction
      - 3. Product: the total amount resulting from multiplication
      - 4. Exponent: a superscript which indicates the number of times a quantity is multiplied by itself
      - 5. Quotient: the amount resulting from division

II. Use a Few Easy-to-Remember Rules to Solve Equations
   - A. *P*lease *E*xcuse *M*y *D*ear *A*unt *S*ue indicates the order in which equations are solved. Each letter shows one of the algebraic notations or functions: Parentheses, Exponents, Multiply, Divide, Add, Subtract.
      - 1. In the expression $(x - y)^2 + 2x^2 - y^2$, the *p*arentheses, which must be worked first, indicate that y must be subtracted from x. Since we don't know what x and y are, we can't do that, and must move on.
      - 2. The next step is to square the term $(x - y)$, as indicated by the *e*xponent. This gives us $x^2 - 2xy + y^2 + 2x^2 - y^2$.
      - 3. There is no operable *m*ultiplication or *d*ivision in this expression, so we move on.
      - 4. Grouping all the like terms to make seeing the answer easier, we have $x^2 + 2x^2 + y^2 - y^2 - 2xy$.
      - 5. *A*dding, we now have $3x^2 + y^2 - y^2 - 2xy$.
      - 6. *S*ubtracting, which is the final step, renders $3x^2 - 2xy$.

B. *FOIL* gives the order in which you multiply the terms in expressions. Let us go back to squaring (multiplying by itself) $(x - y)$ from the expression above.

1. *F*irst terms first, so, in $(x - y)(x - y)$, multiply the two x's first. This give us x^2.
2. *O*utside terms come next, so multiply the first x by the second y. This gives us $x^2 - xy$.
3. *I*nside terms come next, so multiply the first y by the second x. This gives us $x^2 - xy - xy$.
4. *L*ast terms are last, so multiply the two y's. This gives us a complete (if complex) $x^2 - xy - xy + y^2$.
5. Simplifying gives us the expression $x^2 - 2xy + y^2$.

C. Thinking about algebra can be daunting to almost anybody, but once you see that algebra is just juggling done with numbers and with a lot of two-dollar words stuck all over it, algebra becomes rather simple. Remember, algebra is just taking the four basic mathematic operations (addition, subtraction, multiplication, and division) and using them to find out something that you didn't know to start with.

D. Word problems are what you will encounter every day in the shop. Someone will tell you to get so much material and make so many parts from it. As you progress in skill, they will tell you to get such-and-such material and make so many parts from it. Your mastery of basic algebra will make these problems easy to solve.

Name_________________________ Date_____________________

CNC-B4
Perform Basic Algebraic Operations
Self-Assessment

Answer the following questions by circling the most correct answer.

1. The technician is given an order for 100 six-inch bars of 1" CRS. If the company stores its 1" CRS in ten-foot lengths, how many lengths of 1" CRS must the technician obtain in order to complete the job? You may assume that there is no waste.
   A. Five
   B. Ten
   C. Twenty
   D. Twenty-five
   E. None of the above answers is correct.

2. The technician is now told to turn all those six-inch bars down from 1" to 7/8". How much must the technician take off each bar?
   A. 1/16"
   B. 2/16"
   C. 3/16"
   D. 4/16"
   E. None of the above answers is correct.

3. A technician must bore three holes in a 90° arc. The holes must be equally spaced along the arc, and Hole 1 is at the baseline (0°). What is the angle between Hole 1 and Hole 2?
   A. 15°
   B. 30°
   C. 45°
   D. 60°
   E. None of the above answers is correct.

4. A technician must bore three holes in a 90° arc. The holes must be equally spaced along the arc, and Hole 1 is at the baseline (0°). What is the angle between Hole 1 and Hole 3?
   A. 15°
   B. 30°
   C. 45°
   D. 60°
   E. None of the above answers is correct.

5. From a twelve-inch bar, the technician must cut two pieces such that one piece is twice as long as the other. What are the lengths of the resultant bars?
   A. 2" & 4"
   B. 3" & 6"
   C. 4" & 8"
   D. 5" & 10"
   E. None of the above answers is correct.

6. Whitworth threads require that the depth of the thread be .64 of the length of the pitch of the thread. If the thread pitch is 1/8 inch, what is the depth of the threads?
   A. .195 inch
   B. 5.12 inch
   C. .08 inch
   D. .765 inch
   E. None of the above answers is correct.

7. On spur gears, the tooth thickness equals 1.5708/P (the diametral pitch). If the diametral pitch of the gear is 24, what is the thickness of the teeth?
   A. .065"
   B. .377"
   C. .153"
   D. .655"
   E. None of the above answers is correct.

8. The finishing speed for low-carbon steels is 120 surface feet per minute (CS). The diameter of a given workpiece is 3" (D). Using the formula for determining machine speeds, rpm = (4 x CS)/D, what is the rpm?
   A. 10
   B. 160
   C. 1440
   D. Not enough information is given to solve the problem.
   E. None of the above answers is correct.

9. The technician must cut twenty-four plates, each 3" x 6". If the stock is one foot wide and three feet long, how many plates can the technician cut from one plate? Assume no waste or thickness of cut.
   A. 6
   B. 12
   C. 24
   D. 36
   E. None of the above answers is correct.

10. If the thickness of the saw blade is 1/8", how many bars, each exactly 6" long, can be cut from one three-foot piece of stock?

A. 3
B. 4
C. 5
D. 6
E. None of the above answers is correct.

CNC-B4
Perform Basic Algebraic Operations
Self-Assessment Answer Key

1. A
2. B
3. C
4. E
5. C
6. C
7. A
8. B
9. C
10. C

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-B5

Subject: Advanced CNC and CAM **Time:** 20 Hrs.

Duty: Apply Mathematical Concepts
Task: Use Practical Geometry

Objective(s):

Upon completion of this module the student will be able to:
a. Calculate angles;
b. Calculate length of triangle sides;
c. Calculate radius, diameter, circumference, and area of a circle; and,
d. Understand the applications of planar geometry to solid forms.

Instructional Materials:

MASTER Handout (CNC-B5-HO);
MASTER Self-Assessment;
Paper
Pencil
Chalk Board
Overhead Projector
Various Geometric Objects

References:

Applied Electronic Math, with Calculators, Tontsch, John W., Latest Edition

Applied Math, Bajpai, Avi C.; Bond, Rodney M.; adapted by Jerry W. Jones, Latest Edition

Applied Math for Technicians, Moore, Claude S.; Griffin, Bennie L.; Polhamus, Edward C., Jr.; {drawings, George E. Morris.}, Latest Edition

Basic Business Math, Dansby, Robert L., Latest Edition

Basic Electronics Math with a Scientific Calculator, by Noll, Edward M., Latest Edition

Becoming a Mental Math Wizard, Lucas, Jerry, Latest Edition

Building Success in Math, Langbort, Carol R.; Thompson, Virginia H., Latest Edition

Business Math Basics, Swindle, Robert E., Latest Edition

Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-B1	"Perform Basic Arithmetic Functions"
CNC-B4	"Perform Basic Algebraic Operations"

Introduction:

Geometry is used to calculate lengths, angles, arcs, areas, and volumes of various shapes and objects. These shapes and objects are the meat and bread of machining; they are machining's sole purpose for existence. The technician takes a workpiece that may not bear any resemblance at all to the finished part, and turns it into that part. A basic understanding of these shapes and how they relate to each other is necessary to the survival of the technician. These shapes and relationships are also geometry.

Presentation Outline:

I. Some Rules of Angles
  A. Angles are usually expressed in degrees, minutes, and seconds
  B. No angle has more than 360°
  C. Angles have three points which determine them
  D. An angle having 90° is a right angle
II. Triangles
  A. Pythagorean Theorem: $a^2 + b^2 = c^2$
  B. All the angles in a triangle will add up to 180°, every day, every time, every triangle
  C. Have three corners. If one of them is 90°, then it is a right triangle.
  D. The absolute size of a triangle cannot be determined by its angles alone. At least one side must be known.
III. Circle
  A. 360°, every day, every time, every circle
  B. Pi (π) 3.1416 and its importance
  C. $2\pi r = d$, where r is the circle's radius and d, its diameter
IV. Rectangles and Parallelograms
  A. Squares and rectangles
    1. Have four 90° corners
    2. Squares are rectangles all of whose sides are equal
  B. Parallelograms
    1. Have four corners not 90°

2. Have (at least) two parallel sides

V. Relating Planar Geometry to Solid Forms

In reality, planar geometry is an abstract way of looking at *parts* of solid things. Look at a piece of 1" CRS—at each end, it is a circle, so all the rules of circles apply to it, but only when looked at from the end. When you look at it from the sides, the rules for lines apply. So, that piece of 1" CRS, which is actually a cylinder, can be looked at as two circles joined by a line. Square workpieces have the same properties. No matter which way you look at them, each face is a rectangle or a parallelogram; and each face is subject to the rules of rectangles and parallelograms. Tapers are unequal circles joined by an incomplete triangle.

Practical Application:

Students will practice working math problems.

Evaluation and/or Verification:

Successful completion of this Technical Module will be based on the student's successful completion of the written evaluation.

Summary:

Review the main lesson points using the handout (CNC-B5-HO) as a guide for discussion and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-B6) dealing with understanding basic trigonometry.

CNC-B5-HO
Use Practical Geometry
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this module the student will be able to:

- a. Calculate angles;
- b. Calculate length of triangle sides;
- c. Calculate radius, diameter, circumference, and area of a circle; and,
- d. Understand the applications of planar geometry to solid forms.

Module Outline:

- I. Some Rules of Angles
  - A. Angles are usually expressed in degrees, minutes, and seconds
  - B. No angle has more than 360°
  - C. Angles have three points which determine them
  - D. An angle having 90° is a right angle
- II. Triangles
  - A. Pythagorean Theorem: $a^2 + b^2 = c^2$
  - B. All the angles in a triangle will add up to 180°, every day, every time, every triangle
  - C. Have three corners. If one of them is 90°, then it is a right triangle.
  - D. The absolute size of a triangle cannot be determined by its angles alone. At least one side must be known.
- III. Circle
  - A. 360°, every day, every time, every circle
  - B. Pi (π) 3.1416 and its importance
  - C. $2\pi r = d$, where r is the circle's radius and d, its diameter
- IV. Rectangles and Parallelograms
  - A. Squares and rectangles
    - 1. Have four 90° corners
    - 2. Squares are rectangles all of whose sides are equal
  - B. Parallelograms
    - 1. Have four corners not 90°
    - 2. Have (at least) two parallel sides
- V. Relating Planar Geometry to Solid Forms

  In reality, planar geometry is an abstract way of looking at *parts* of solid things. Look at a piece of 1" CRS—at each end, it is a circle, so all the rules of circles apply to it, but only when looked at from the end. When you look at it from the sides, the rules for lines apply. So, that piece of 1" CRS, which is actually a cylinder, can be looked at as two circles joined by a line. Square workpieces have the same properties. No matter which way you look at them, each face is a rectangle or a parallelogram; and each face is subject to the rules of rectangles and parallelograms. Tapers are unequal circles joined by an incomplete triangle.

Name________________________ Date____________________

CNC-B5
Use Practical Geometry
Self-Assessment

Solve the following problems:

1. The technician is told to turn down a three-inch piece of 1" CRS to 3/4". What is the length of the new radius of the CRS?
   - A. .750"
   - B. .500"
   - C. .375"
   - D. .125"
   - E. None of the above answers is correct.

2. The technician must bore six 1" holes in a plate. The holes must be bored in a eight-inch diameter circle and must be equally spaced. How many degrees apart are the holes?
   - A. 30°
   - B. 60°
   - C. 90°
   - D. 120°
   - E. None of the above answers is correct.

3. The technician must cut triangular iron plates for a construction project. One angle is 80° and one of the others is 50°. What is the measure of the third angle?
   - A. 230°
   - B. 165°
   - C. 50°
   - D. Not enough information is given to solve the problem.
   - E. None of the above answers is correct.

4. The technician is given six discs, each 3" in diameter. Each disc must be bored so that it produces an eccentricity of 1/2". How far off center does the technician drill the hole?
   - A. 1/8"
   - B. 1/4"
   - C. 1/2"
   - D. 1/4π"
   - E. None of the above answers is correct.

5. The technician must cut a set of 1/2" square teeth along the top of a 6' rectangular rod. The top flat and the valley flat are equal and each end of the rod ends in a top flat. How many valley flats must be cut? (Note: There will be scrap.)

A. 36
B. 71
C. 70
D. 102
E. None of the above answers is correct.

CNC-B5
Use Practical Geometry
Self-Assessment Answer Key

1. C
2. B
3. C
4. B
5. B

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-B6

Subject: **Advanced CNC and CAM** **Time: 4 Hrs.**

Duty: **Apply Mathematical Concepts**
Task: Understand Basic Trigonometry

Objective(s):

Upon completion of this unit the student will be able to:

a. Solve for unknown angles;
b. Solve for unknown sides; and,
c. Calculate bolt hole patterns.

Instructional Materials:

Scientific Calculator capable of trigonometric functions
MASTER Handout (CNC-B6-HO)
MASTER Laboratory Aid (CNC-B6-LA)
MASTER Self-Assessment

References:

Machinery's Handbook, Industrial Press, Latest Edition, "Solution of Triangles"
Student's Shop Reference Handbook, Industrial Press, Latest Edition, "Mathematics: Solution of Triangles"

Student Preparation:

Students should have previously completed the following Technical Modules:
CNC-B1 "Perform Basic Arithmetic Functions"

Introduction:

Trigonometry for the machinist is actually quite simple. There is nothing to memorize and the calculations are easy. It is important, however, to the operation of several measuring devices and tools.

Presentation Outline:

- I. Solve for Unknown Angles
  - A. Right triangles
    - 1. Sine Law: sin a = side opposite divided by hypotenuse
    - 2. Cosine Law: cos a = side adjacent divided by hypotenuse
    - 3. Tangent Law: tan a = side opposite divided by side adjacent
    - 4. *Oscar* *H*as *A* *H*eap *Of* *A*pples is a quick device to remember the above three runes.
      - a. Sine ∠ = *O*pposite/*H*ypoteneuse
      - b. Cosine ∠ = *A*djacent/*H*ypoteuse
      - c. Tangent ∠ = *O*pposite/*A*djacent
  - B. Oblique Triangles
    - 1. Lengths of three sides (A, B, C) all known
      - a. $\text{Cos}\ a = (B^2 + C^2 - A^2)/2BC$
      - b. $\text{Sin}\ b = (B \times \sin a)/A$
      - c. $c = 180° - (a + b)$
    - 2. Two angles (a and b) known

      $c = 180° - (a + b)$
    - 3. Two sides and interior angle (A, c, B) known
      - a. $\text{Tan}\ a = (A \times \sin c)/B-(A \times \cos c)$
      - b. $b = 180° - (a + c)$
      - c. $C = (A \times \sin c)/\sin a$
    - 4. Two sides and an opposite angle (a, A, B) known
      - a. $\text{Sin}\ b = (B \times \sin a)/A$
      - b. $c = 180° - (a + b)$
      - c. $C = (A \times \sin c)/\sin a$
- II. Solve for Unknown Sides
  - A. Right triangles, any two sides known, where C is the hypotenuse

    $A^2 + B^2 = C^2$
  - B. One side and two angles (a, b, A) known
    - 1. $c = 180° - (a + b)$
    - 2. $B = (A \times \sin b)/\sin a$
    - 3. $C = (A \times \sin c)/\sin a$
  - C. Two sides and the interior angle (A, B, c) known

    $C = \sqrt{[A^2 + B^2 - (2AB \times \cos c)]}$
  - D. Three angles known

    It is impossible to determine the actual length of any side when only the sizes of the three angles are known. The length of at least one side *must* be known in order to calculate the lengths of the other sides.
- III. Calculate Bolt Hole Patterns
  - A. Discuss the construction of reference triangles to solve bolt-hole patterns
  - B. Discuss circles and their uses in figuring bolt-hole patterns.

Practical Application:

Students will display the ability to correctly lay out bolt hole patterns and to compute angular distances using trigonometry. This module also prepares students for the use of sine bars and sine plates.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-B7) dealing with calculating speeds and feeds for machining.

CNC-B6-HO
Understand Basic Trigonometry
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:
- a. Solve for unknown angles;
- b. Solve for unknown sides; and,
- c. Calculate bolt hole patterns.

Module Outline:

- I. Solve for Unknown Angles
  - A. Right triangles
    - 1. Sine Law: $\sin a$ = side opposite divided by hypotenuse
    - 2. Cosine Law: $\cos a$ = side adjacent divided by hypotenuse
    - 3. Tangent Law: $\tan a$ = side opposite divided by side adjacent
    - 4. *O*scar *H*as *A* *H*eap *O*f *A*pples is a quick device to remember the above three runes.
      - a. Sine ∠ = *O*pposite/*H*ypoteneuse
      - b. Cosine ∠ = *A*djacent/*H*ypoteuse
      - c. Tangent ∠ = *O*pposite/*A*djacent
  - B. Oblique Triangles
    - 1. Lengths of three sides (A, B, C) all known
      - a. $\cos a = (B^2 + C^2 - A^2)/2BC$
      - b. $\sin b = (B \times \sin a)/A$
      - c. $c = 180° - (a + b)$
    - 2. Two angles (a and b) known
      $c = 180° - (a + b)$
    - 3. Two sides and interior angle (A, c, B) known
      - a. $\tan a = (A \times \sin c)/B-(A \times \cos c)$
      - b. $b = 180° - (a + c)$
      - c. $C = (A \times \sin c)/\sin a$
    - 4. Two sides and an opposite angle (a, A, B) known
      - a. $\sin b = (B \times \sin a)/A$
      - b. $c = 180° - (a + b)$
      - c. $C = (A \times \sin c)/\sin a$
- II. Solve for Unknown Sides
  - A. Right triangles, any two sides known, where C is the hypotenuse
    $A^2 + B^2 = C^2$
  - B. One side and two angles (a, b, A) known
    - 1. $c = 180° - (a + b)$
    - 2. $B = (A \times \sin b)/\sin a$

3. $C = (A \times \sin c)/\sin a$

C. Two sides and the interior angle (A, B, *c*) known
$C = \sqrt{[A^2 + B^2 - (2AB \times \cos c)]}$

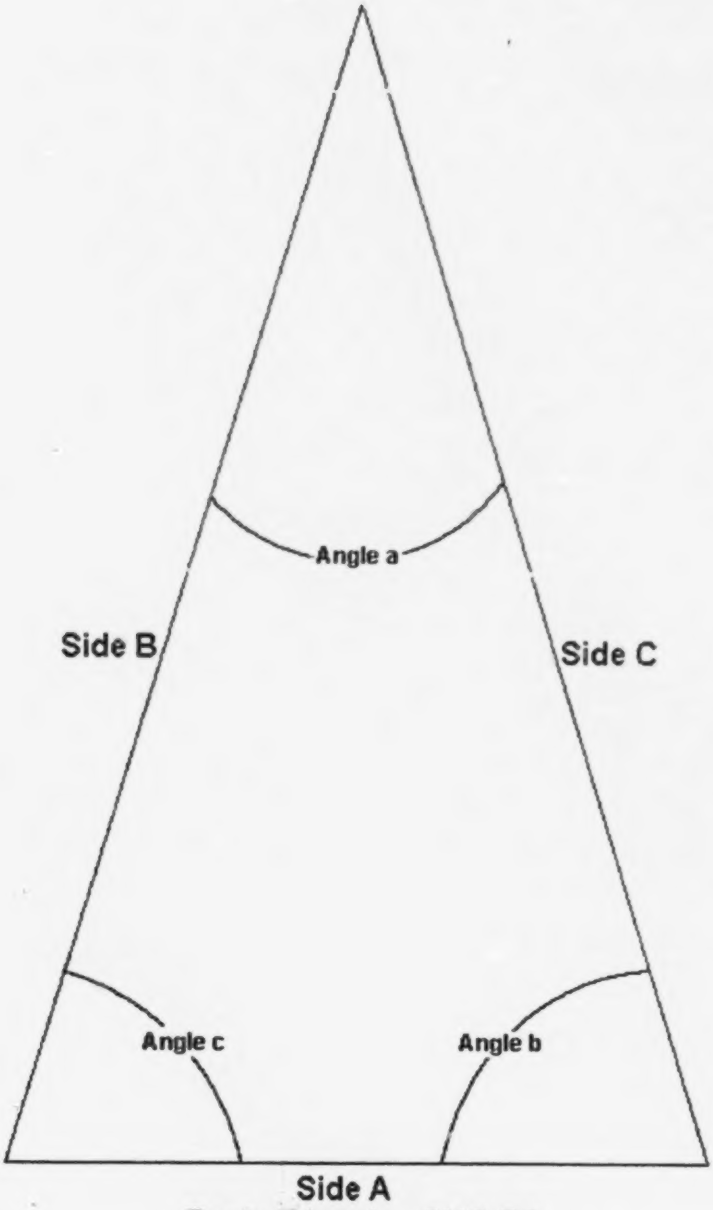
D. Three angles known
It is impossible to determine the actual length of any side when only the sizes of the three angles are known. The length of at least one side *must* be known in order to calculate the lengths of the other sides.

III. Calculate Bolt Hole Patterns

A. Discuss the construction of reference triangles to solve bolt-hole patterns

B. Discuss circles and their uses in figuring bolt-hole patterns.

CNC-B6-LA
Understand Basic Trigonometry
Attachment 2: MASTER Laboratory Aid


Angle a
Side B
Side C
Angle c
Angle b
Side A

Basic Triangle - CNC-B6

Name______________________________ Date________________

CNC-B6
Understand Basic Trigonometry
Self-Assessment

Using the reference triangle on the accompanying page, solve the following triangles from the information given. Show all work.

1. Side A = 9"; Side B = 8"; Side C = 12"; solve for all angles. The triangle is oblique.

2. Side A = 6 cm; Angle *c* = 60°; Side B = 12 cm; solve for Angle *a*..

3. Angle *a* = 35°; Angle *b* = 57° 30'; solve for Angle *c*.

4. Angle *a* = 40°; Side A = 18"; Side B = 12"; solve for Angles *b* & *c*.

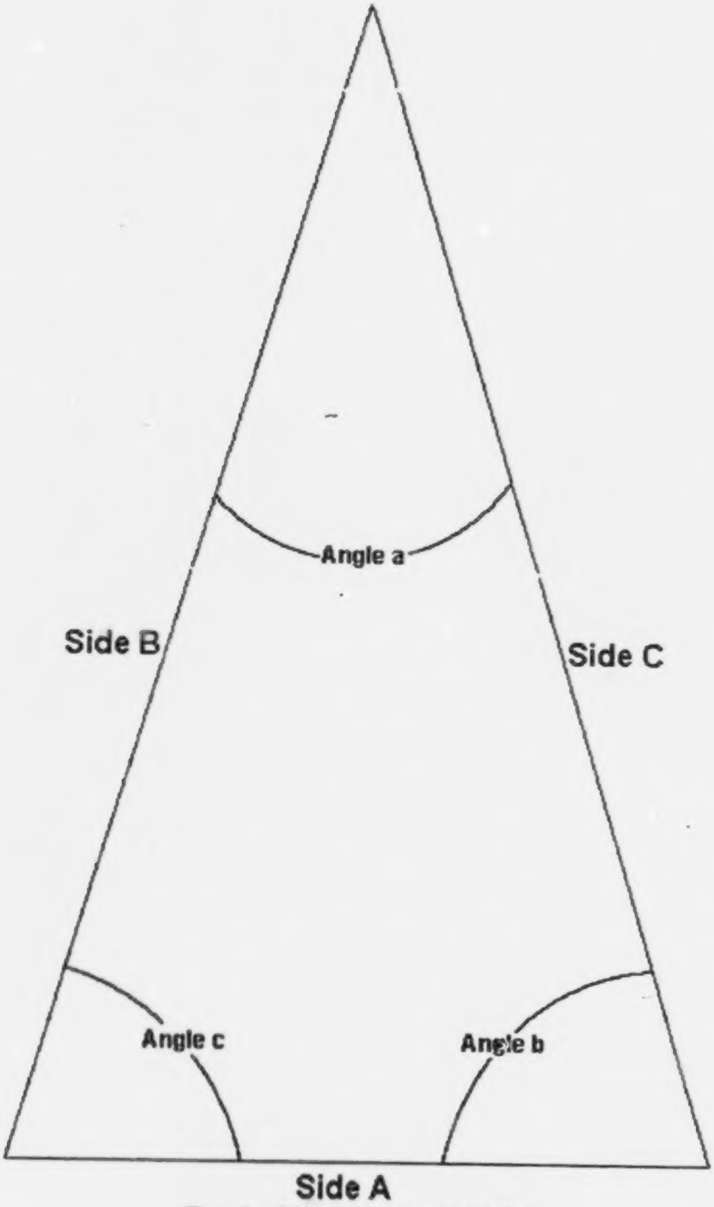
5. Side A = cm; Angle *c* = 90°; Side B = 12 cm; solve for Side C.

6. Angle *a* = 22° 30'; Angle *b* = Angle *a*; Side A = 9"; solve for Sides B & C.

7. Side A = 12 cm; Side B = 12 cm; Angle *c* = 60°; solve for Side C.

8. The triangle is a right triangle. Side A = 3'; Side B = 4'; Side C = 5'; solve for all angles.

9. A right triangle has two 45° angles. Solve for the sides, in inches.

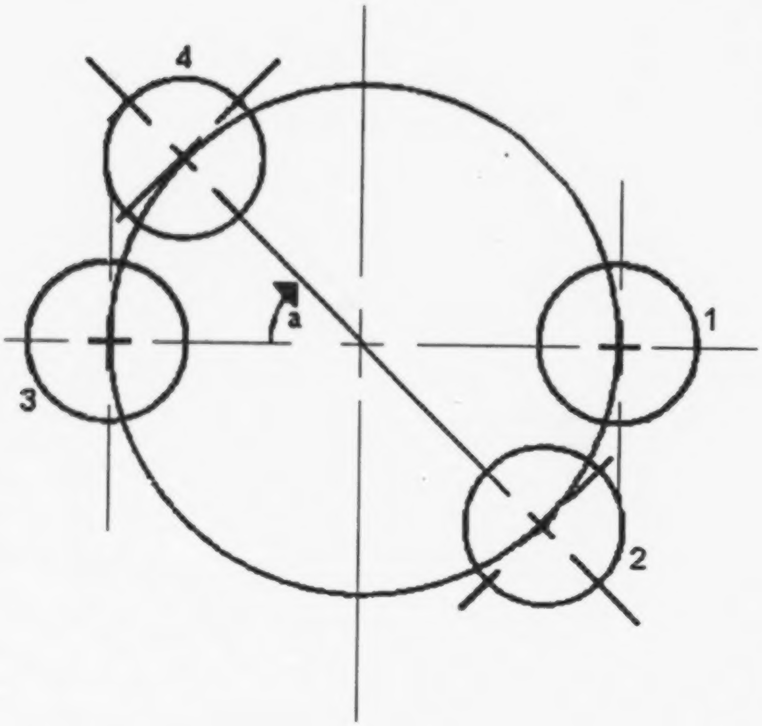

Angle a
Side B
Side C
Angle c
Angle b
Side A

Basic Triangle - CNC-B6

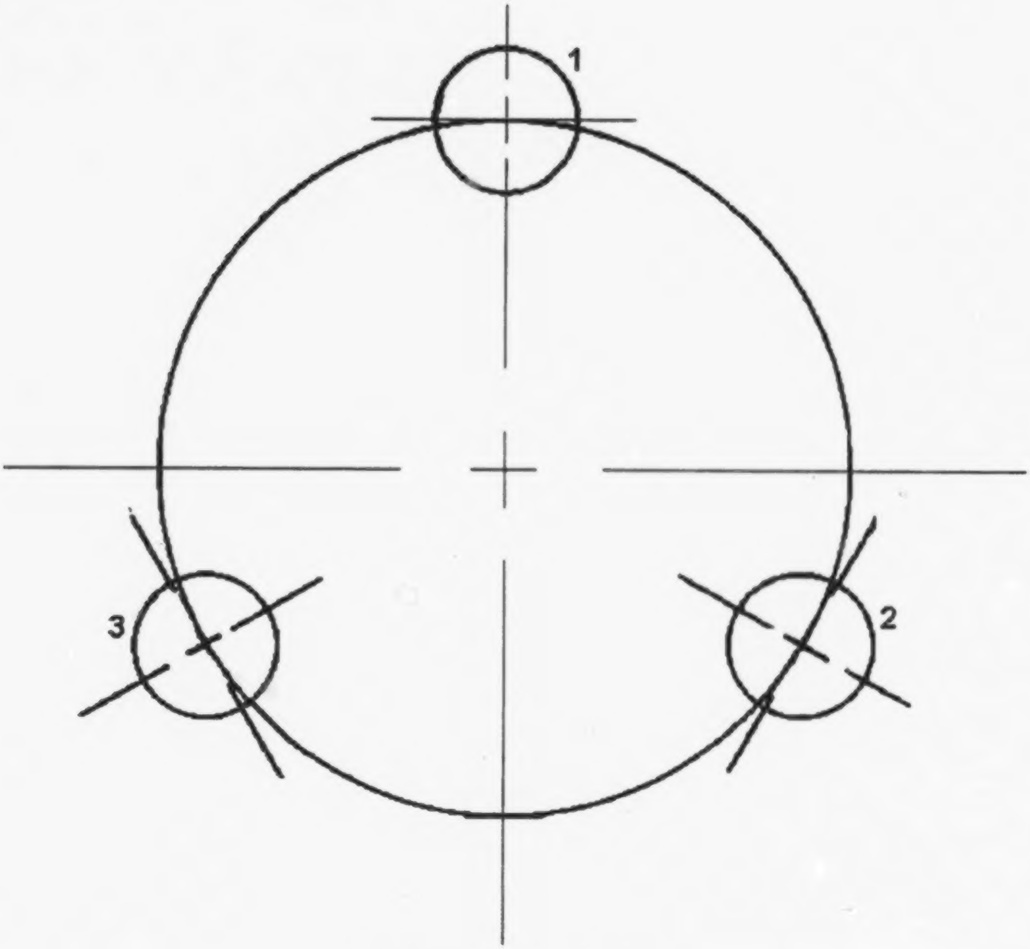
Using the two bolt-hole patterns shown in the illustrations on the accompanying pages, solve the following questions. Remember that the answers should be in the form of *x,y*.

10. Four holes are spaced around a 2" semi-circle. If Hole One is at 1,0; where are the other three holes?

11. Three equally-spaced holes around a 6" diameter reference circle. If Hole One is at 0,3; where are the other two holes?



Question No. 10 - CNC-B6



Question No. 11 - CNC-B6

CNC-B6
Understand Basic Trigonometry
Self-Assessment Answer Key

1. a = 48.59°   b = 41.81°   c = 89.6°

2. a = 86.11°

3. c = 87° 30'

4. b = 25.37°   c =114.63°

5. Side C = 13.41 cm

6. Side B = 9"   Side C = 16.63"

7. Side C = 12 cm

8. Angle a = 36.87°   Angle b = 53.13°   Angle c = 90°

9. The problem is impossible to solve.

10. Hole 1: 1,0   Hole 2: 0.7071, -0.7071
    Hole 3: -1,0   Hole 4: -0.7071, 0.7071

11. Hole 1: 0, 3   Hole 2: 0.866, -0.500   Hole 3: -0.500, -0.866

CNC-B7

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-B7

Subject: **Advanced CNC and CAM** **Time: 6 Hrs.**

Duty: **Apply Mathematical Concepts**
Task: Calculate Speeds and Feeds for Machining

Objective(s):

Upon completion of this unit the student will be able to:

a. Calculate RPM for various metals and various tools; and,
b. Calculate feed for various metals, tools, and depths of cut.

Instructional Materials:

MASTER Handout (CNC-B7-HO)
MASTER Laboratory Aid (CNC-B7-LA)
MASTER Self-Assessments (two)

References:

Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition, Section F: Preparation for Machining Operations, Unit 2: Speeds and Feeds for Machine Tools

Machinery's Handbook, Industrial Press, Latest Edition, "Cutting Feeds and Speeds"

NTMA Modules:

- **MA-I-22** "Milling Machines: Speeds & Feeds/Problems"
- **MA-I-36** "Engine Lathe: Selecting Speeds & Feeds"
- **MA-I-51** "Pocket Calculators: Speeds & Feeds"

Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-B1 "Perform Basic Arithmetic Functions"

Introduction:

The most important decisions which the machinist must make when machining a workpiece are: (1) What are the optimum speeds for each machine operation? If the machine is run too fast or too slow, machining time and part quality may be greatly sacrificed. (2) What are the optimum feeds for each machine operation? If the tool is

fed into the work too fast or too slow production rates may be reduced significantly. (3) What depths of cuts will remove excess material and bring the part to the desired size most quickly? If too shallow of cuts are made, much time will be wasted and desired surface finish will not be achieved. One of the characteristics of an expert machinist is the ability choose the most efficient speeds, feeds and depths of cuts for the parts he is called on to machine.

Presentation Outline:

- I. Calculate RPM for Various Metals and Various Tools
  - A. Cutting speed (CS) defined - the surface feet per minute (sf/min) or meters per minute (m/min) at which the metal may be machined efficiently. When work is machined on a lathe, it must be turned at a specific number of revolutions per minute (rpm), *depending on its diameter*, to achieve the proper cutting speed. When work is machined on a milling machine, the cutter must be revolved at a specified number of rpm's, *depending on its diameter*, to achieve the proper cutting speed.
  - B. Factors affecting proper cutting speed
    - 1. Type of work material (aluminum, bronze, steel, etc.)
    - 2. Type of cutter (high-speed, carbide etc.)
    - 3. Diameter of the cutter
    - 4. Surface finish required
    - 5. Depth of cut
    - 6. Rigidity of the machine and the work setup
  - C. Sources for determining recommended cutting speeds
    - 1. ***Machinery's Handbook***
    - 2. The text
    - 3. Cutting tool and insert manufacturers
    - 4. Experience of the machinist
  - D. Determining correct RPM
    - 1. Inch RPM calculations ...

      $RPM = (CS \times 4) \div Diam.$
    - 2. Metric RPM calculations ...

      $RPM = (CS\ (m) \times 1000) \div (\pi \times Diam.\ (mm))$
    - 3. See charts 7.1 and 7.2 in this module
  - E. Problems related to using the wrong cutting speed
    - 1. Cutting speed too slow
      - a. Time will be lost for machining (low production rates)
      - b. Broken tool bits
    - 2. Cutting speed too fast
      - a. Cutting tool edge breaks down
      - b. Loss in production time due to reconditioning/replacing the tool

F. Student practice using the "Determining Correct RPM" exercise and recommended speed charts found in this module

II. Calculate Feed for Various Metals, Tools, and Depths of Cut

A. Feed defined - feed may be defined as the distance the tool advances into the work for every revolution.
  1. When work is machined on a lathe, feed is the distance, in inches (or millimeters), the cutting tool advances along the length of the work for every revolution of the spindle. Lathe feeds are generally expressed as inches (or millimeters) per revolution (ipr).
  2. When work is machined on a milling machine, feed is the distance, in inches (or millimeters) per minute, that the work moves into the cutter. Milling feeds are generally expressed as inches (or millimeters) per minute (ipm).

B. Factors affecting proper feed
  1. Depth and width of cut
  2. Design or type of cutter
  3. Sharpness of the cutter
  4. Workpiece material
  5. Strength and uniformity of the workpiece
  6. The of finish and accuracy required
  7. Power and rigidity of the machine

C. Sources for determining cutting optimal cutting speeds
  1. *Machinery's Handbook*
  2. The text
  3. Cutting tool and insert manufacturers
  4. Experience of the machinist

D. Methods for determining correct feed
  1. Depth of cut - rule of thumb
    a. When possible, only two cuts should be used to bring a part to size: a roughing cut and a finishing cut.
    b. Since the purpose of a roughing cut is to remove excess material quickly and surface finish is not too important, a heavy depth of cut with a course feed should be used.
    c. The finishing cut is used to bring the diameter to size and produce a good surface finish and therefore a lighter depth of cut with a fine feed should be used.
    d. If much material must be removed, the roughing cuts should be as deep as possible to reduce the size of the part to within .020" to .030" of the size required.
  2. Lathe feed guidelines
    1. Roughing - .010" to .030" (.25 mm to .75 mm) per revolution
    2. Finishing - .003" to .010" (.07 mm to .25 mm) per revolution

3. See chart 7.4 in this module

3. Mill feed guidelines
   a. Inch feed calculation ...
      Feed (ipm) = N x chip per tooth x RPM
      where N = number of teeth on the cut
   b. Metric feed calculation ... feed (mm/min) = same as above
   c. See charts 7.4 and 7.5 in this module

E. Problems related to using the wrong feed
   1. Feed speed too slow
      a. Time will be lost for machining (low production rates)
      b. Broken tool bits
   2. Feed too fast
      a. Cutting tool edge breaks down
      b. Loss in production time due to reconditioning/replacing the tool

F. Student practice using the "Calculate Speeds and Feeds for Machining" exercise and the recommended feed charts found in this module

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Practical Application:

Students should successfully complete the two Self-Assessments found in this lesson.

Evaluation and/or Verification:

Students should make 90% or above on the two Self-Assessments found in this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-B8) dealing with coordinate systems.

CNC-B7-HO
Calculate Speeds and Feeds for Machining
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Calculate RPM for various metals and various tools; and,
b. Calculate feed for various metals, tools, and depths of cut.

Module Outline:

I. Calculate RPM for Various Metals and Various Tools
  A. Cutting speed (CS) defined - the surface feet per minute (sf/min) or meters per minute (m/min) at which the metal may be machined efficiently. When work is machined on a lathe, it must be turned at a specific number of revolutions per minute (rpm), *depending on its diameter*, to achieve the proper cutting speed. When work is machined on a milling machine, the cutter must be revolved at a specified number of rpm's, *depending on its diameter*, to achieve the proper cutting speed.
  B. Factors affecting proper cutting speed
    1. Type of work material (aluminum, bronze, steel, etc.)
    2. Type of cutter (high-speed, carbide etc.)
    3. Diameter of the cutter
    4. Surface finish required
    5. Depth of cut
    6. Rigidity of the machine and the work setup
  C. Sources for determining recommended cutting speeds
    1. *Machinery's Handbook*
    2. The text
    3. Cutting tool and insert manufacturers
    4. Experience of the machinist
  D. Determining correct RPM
    1. Inch RPM calculations ...
      RPM = (CS x 4) ÷ Diam.
    2. Metric RPM calculations ...
      RPM = (CS (m) x 1000) ÷ (π x Diam. (mm))
    3. See charts 7.1 and 7.2 in this module
  E. Problems related to using the wrong cutting speed
    1. Cutting speed too slow
      a. Time will be lost for machining (low production rates)
      b. Broken tool bits
    2. Cutting speed too fast

- a. Cutting tool edge breaks down
- b. Loss in production time due to reconditioning/replacing the tool

F. Student practice using the "Determining Correct RPM" exercise and recommended speed charts found in this module

II. Calculate Feed for Various Metals, Tools, and Depths of Cut

A. Feed defined - feed may be defined as the distance the tool advances into the work for every revolution.

1. When work is machined on a lathe, feed is the distance, in inches (or millimeters), the cutting tool advances along the length of the work for every revolution of the spindle. Lathe feeds are generally expressed as inches (or millimeters) per revolution (ipr).
2. When work is machined on a milling machine, feed is the distance, in inches (or millimeters) per minute, that the work moves into the cutter. Milling feeds are generally expressed as inches (or millimeters) per minute (ipm).

B. Factors affecting proper feed

1. Depth and width of cut
2. Design or type of cutter
3. Sharpness of the cutter
4. Workpiece material
5. Strength and uniformity of the workpiece
6. The of finish and accuracy required
7. Power and rigidity of the machine

C. Sources for determining cutting optimal cutting speeds

1. *Machinery's Handbook*
2. The text
3. Cutting tool and insert manufacturers
4. Experience of the machinist

D. Methods for determining correct feed

1. Depth of cut - rule of thumb
    - a. When possible, only two cuts should be used to bring a part to size: a roughing cut and a finishing cut.
    - b. Since the purpose of a roughing cut is to remove excess material quickly and surface finish is not too important, a heavy depth of cut with a course feed should be used.
    - c. The finishing cut is used to bring the diameter to size and produce a good surface finish and therefore a lighter depth of cut with a fine feed should be used.
    - d. If much material must be removed, the roughing cuts should be as deep as possible to reduce the size of the part to within .020" to .030" of the size required.
2. Lathe feed guidelines

      1. Roughing - .010" to .030" (.25 mm to .75 mm) per revolution
      2. Finishing - .003" to .010" (.07 mm to .25 mm) per revolution
      3. See chart 7.4 in this module
   3. Mill feed guidelines
      a. Inch feed calculation ...
         Feed (ipm) = N x chip per tooth x RPM
         where N = number of teeth on the cut
      b. Metric feed calculation ... feed (mm/min) = same as above
      c. See charts 7.4 and 7.5 in this module

E. Problems related to using the wrong feed
   1. Feed speed too slow
      a. Time will be lost for machining (low production rates)
      b. Broken tool bits
   2. Feed too fast
      a. Cutting tool edge breaks down
      b. Loss in production time due to reconditioning/replacing the tool

F. Student practice using the "Calculate Speeds and Feeds for Machining" exercise and the recommended feed charts found in this module

CNC-B7-LA
Calculate Speeds and Feeds for Machining
Attachment 2: MASTER Laboratory Aid

TABLE 7.1

Lathe Cutting Speeds in Feet & Meters Per Minute Using a High-Speed Toolbit

Material	Turning & Boring				Threading	
	Rough Cut		Finish Cut			
	ft/min	m/min	ft/min	m/min	ft/min	m/min
Machine Steel	90	27	100	30	35	11
Tool Steel	70	21	90	27	30	9
Cast Iron	60	18	80	24	25	8
Bronze	90	27	100	30	25	8
Aluminum	200	61	300	93	60	18

TABLE 7.2

Milling Machine Cutting Speeds

Material	High-Speed Steel Cutter		Carbide Cutter	
	ft/min	m/min	ft/min	m/min
Machine Steel	70-100	21-30	150-250	45-75
Tool Steel	60-70	18-20	125-200	40-60
Cast Iron	50-80	15-25	125-200	40-60
Bronze	65-120	20-35	200-400	60-120
Aluminum	500-1000	150-300	1000-2000	150-300

TABLE 7.3

Feeds for Various Materials (Using a High-Speed Cutting Tool)

Materials	Rough Cuts		Finish Cuts	
	Inches	Millimeters	Inches	Millimeters
Machine Steel	0.010-0.020	0.25-0.50	0.003-0.010	0.07-0.25
Tool Steel	0.010-0.020	0.25-0.50	0.003-0.010	0.07-0.25
Cast Iron	0.015-0.025	0.40-0.65	0.005-0.012	0.13-0.30
Bronze	0.015-0.025	0.40-0.65	0.003-0.010	0.07-0.25
Aluminum	0.015-0.030	0.40-0.75	0.005-0.010	0.13-0.25

TABLE 7.4

Recommended Feed per Tooth (High-Speed Steel Cutters)

Material	**Face Mills**		**Helical Mills**		**Slotting & Side Mills**		**End Mills**		**Form-Relieved Cutters**	
	In.	**mm**	**In.**	**mm**	**In.**	**mm**	**In.**	**mm**	**In.**	**mm**
Aluminum	0.022	0.55	0.018	0.45	0.013	0.33	0.011	0.28	0.007	0.18
Brass & Bronze (medium)	0.014	0.35	0.011	0.28	0.008	0.20	0.007	0.18	0.004	0.10
Cast Iron (medium)	0.013	0.33	0.010	0.25	0.007	0.18	0.007	0.18	0.004	0.10
Machine Steel	0.012	0.30	0.010	0.25	0.007	0.18	0.006	0.15	0.004	0.10
Tool Steel (medium)	0.010	0.25	0.008	0.20	0.006	0.15	0.005	0.13	0.003	0.08
Stainless Steel	0.006	0.15	0.005	0.13	0.004	0.10	0.003	0.08	0.002	0.05

TABLE 7.5

Recommended Feed per Tooth (Cemented-Carbide-Tipped Cutters)

Material	Face Mills		Helical Mills		Slotting & Side Mills		End Mills		Form-Relieved Cutters	
	In.	**mm**	**In.**	**mm**	**In.**	**mm**	**In.**	**mm**	**In.**	**mm**
Aluminum	0.020	0.50	0.016	0.40	0.012	0.30	0.010	0.25	0.006	0.15
Brass & Bronze (medium)	0.012	0.30	0.010	0.25	0.007	0.18	0.006	0.15	0.004	0.10
Cast Iron (medium)	0.016	0.40	0.013	0.33	0.010	0.25	0.008	0.20	0.005	0.13
Machine Steel	0.016	0.40	0.013	0.33	0.009	0.23	0.008	0.20	0.005	0.13
Tool Steel (medium)	0.014	0.35	0.011	0.28	0.008	0.20	0.007	0.18	0.004	0.10
Stainless Steel	0.010	0.25	0.008	0.20	0.006	0.15	0.005	0.13	0.003	0.08

Name________________________ Date_____________

CNC-B7

Calculate Speeds and Feeds for Machining

Self-Assessment 1

Using Tables 7.1 and 7.2 on the following pages, calculate the correct roughing and finishing speeds for the following materials. Write your answer in the space provided. (Show all work.)

1. Aluminum - 2.0" diameter (Lathe)

   Answer (roughing) = ______ Answer (finishing) = ______

2. Machine steel - .75" (high speed) end mill

   Answer (roughing) = ______ Answer (finishing) = ______

3. Tool steel - .5" (carbide) end mill

   Answer (roughing) = ______ Answer (finishing) = ______

4. Cast iron - 5.0" diameter (Lathe)

   Answer (roughing) = ______ Answer (finishing) = ______

5. Bronze - 1.125" diameter (Lathe)

Answer (roughing) = ______ Answer (finishing) = ______

6. Aluminum - 18 mm (high speed) end mill

Answer (roughing) = ______ Answer (finishing) = ______

7. Bronze - 25 mm diameter (Lathe)

Answer (roughing) = ______ Answer (finishing) = ______

8. Tool steel - 40 mm diameter (Lathe)

Answer (roughing) = ______ Answer (finishing) = ______

9. Machine steel - 12 mm (carbide) end mill

Answer (roughing) = ______ Answer (finishing) = ______

10. Cast iron - 6 mm (high speed) end mill

Answer (roughing) = ______ Answer (finishing) = ______

TABLES FOR CNC-B7
Calculating Speeds and Feeds for Machining

TABLE 7.1

Lathe Cutting Speeds in Feet & Meters Per Minute Using a High-Speed Toolbit						
Material	Turning & Boring				Threading	
	Rough Cut		Finish Cut			
	ft/min	m/min	ft/min	m/min	ft/min	m/min
Machine Steel	90	27	100	30	35	11
Tool Steel	70	21	90	27	30	9
Cast Iron	60	18	80	24	25	8
Bronze	90	27	100	30	25	8
Aluminum	200	61	300	93	60	18

TABLE 7.2

Milling Machine Cutting Speeds				
Material	High-Speed Steel Cutter		Carbide Cutter	
	ft/min	m/min	ft/min	m/min
Machine Steel	70-100	21-30	150-250	45-75
Tool Steel	60-70	18-20	125-200	40-60
Cast Iron	50-80	15-25	125-200	40-60
Bronze	65-120	20-35	200-400	60-120
Aluminum	500-1000	150-300	1000-2000	150-300

CNC-B7

Calculating Speeds and Feeds for Machining

Self-Assessment 1 Answer Key

1. Roughing: 400 RPM
   Finishing: 640 RPM

2. Roughing: 373-1/3 RPM
   Finishing: 533-1/3 RPM

3. Roughing: 480 RPM
   Finishing: 560 RPM

4. Roughing: 48 RPM
   Finishing: 52 RPM

5. Roughing: 320 RPM
   Finishing: 355.556 RPM

6. Roughing: 2652.6 RPM
   Finishing: 5305 RPM

7. Roughing: 343.8 RPM
   Finishing: 382 RPM

8. Roughing: 167 RPM
   Finishing: 215 RPM

9. Roughing: 557 RPM
   Finishing: 37.7 RPM

10. Roughing: 796 RPM
    Finishing: 1326.3 RPM

Name_______________________ Date_____________

CNC-B7
Calculating Speeds and Feeds for Machining
Self-Assessment 2

Using Tables 7.3, 7.4, and 7.5 on the following pages, determine the correct roughing and finishing feeds for the following materials. Write your answer in the space provided. (Show all work.)

1. Aluminum (inch) (Lathe)

   Answer (roughing) = _______ Answer (finishing) = _______

2. Cast iron (inch) (Lathe)

   Answer (roughing) = _______ Answer (finishing) = _______

3. Tool steel (metric) (Lathe)

   Answer (roughing) = _______ Answer (finishing) = _______

4. Machine steel - (.5" diameter, 4 flute, high speed endmill)

Answer (roughing) = _______ Answer (finishing) = _______

5. Tool steel - (4.0" diameter, 6 tooth, insertable carbide face mill)

Answer (roughing) = _______ Answer (finishing) = _______

6. Aluminum - (12 mm diameter, 2 flute, carbide end mill)

Answer (roughing) = _______ Answer (finishing) = _______

TABLES FOR CNC-B7
Calculating Speeds and Feeds for Machining

TABLE 7.3

Feeds for Various Materials (Using a High-Speed Cutting Tool)

Materials	**Rough Cuts**		**Finish Cuts**	
	Inches	**Millimeters**	**Inches**	**Millimeters**
Machine Steel	0.010-0.020	0.25-0.50	0.003-0.010	0.07-0.25
Tool Steel	0.010-0.020	0.25-0.50	0.003-0.010	0.07-0.25
Cast Iron	0.015-0.025	0.40-0.65	0.005-0.012	0.13-0.30
Bronze	0.015-0.025	0.40-0.65	0.003-0.010	0.07-0.25
Aluminum	0.015-0.030	0.40-0.75	0.005-0.010	0.13-0.25

TABLE 7.4

Recommended Feed per Tooth (High-Speed Steel Cutters)

Material	Face Mills		Helical Mills		Slotting & Side Mills		End Mills		Form-Relieved Cutters	
	In.	**mm**	**In.**	**mm**	**In.**	**mm**	**In.**	**mm**	**In.**	**mm**
Aluminum	0.022	0.55	0.018	0.45	0.013	0.33	0.011	0.28	0.007	0.18
Brass & Bronze (medium)	0.014	0.35	0.011	0.28	0.008	0.20	0.007	0.18	0.004	0.10
Cast Iron (medium)	0.013	0.33	0.010	0.25	0.007	0.18	0.007	0.18	0.004	0.10
Machine Steel	0.012	0.30	0.010	0.25	0.007	0.18	0.006	0.15	0.004	0.10
Tool Steel (medium)	0.010	0.25	0.008	0.20	0.006	0.15	0.005	0.13	0.003	0.08
Stainless Steel	0.006	0.15	0.005	0.13	0.004	0.10	0.003	0.08	0.002	0.05

TABLE 7.5

Recommended Feed per Tooth (Cemented-Carbide-Tipped Cutters)

Material	Face Mills		Helical Mills		Slotting & Side Mills		End Mills		Form-Relieved Cutters	
	In.	mm	In.	mm	In.	mm	In.	mm	In.	mm
Aluminum	0.020	0.50	0.016	0.40	0.012	0.30	0.010	0.25	0.006	0.15
Brass & Bronze (medium)	0.012	0.30	0.010	0.25	0.007	0.18	0.006	0.15	0.004	0.10
Cast Iron (medium)	0.016	0.40	0.013	0.33	0.010	0.25	0.008	0.20	0.005	0.13
Machine Steel	0.016	0.40	0.013	0.33	0.009	0.23	0.008	0.20	0.005	0.13
Tool Steel (medium)	0.014	0.35	0.011	0.28	0.008	0.20	0.007	0.18	0.004	0.10
Stainless Steel	0.010	0.25	0.008	0.20	0.006	0.15	0.005	0.13	0.003	0.08

CNC-B7
Calculating Speeds and Feeds for Machining
Self-Assessment 2 Answer Key

1. Roughing: .030 ipr
   Finishing: .005 ipr

2. Roughing: .025 ipr
   Finishing: .005 ipr

3. Roughing: .25 mpr
   Finishing: .25 mpr

4. Roughing: 17.92 ipm
   Finishing: 1.6 ipm

5. Roughing: 5.04 ipm
   Finishing: 5.88 ipm

6. Roughing: 1989.44 ipm
   Finishing: 3978.89 ipm

CNC-B8

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-B8

Subject: **Advanced CNC and CAM** **Time: 6 Hrs.**

Duty: **Apply Mathematical Concepts**
Task: Use Coordinate Systems

Objective(s):

Upon completion of this unit the student will be able to:

a. Identify points using the Cartesian coordinate system;
b. Identify points using the absolute dimensioning system;
c. Identify points using the incremental dimensioning system; and,
d. Identify points using the polar coordinate system.

Instructional Materials:

Scientific calculator
MASTER Handout (CNC-B8-HO)
MASTER Self-Assessment

References:

Student's Shop Reference Handbook, Industrial Press, Latest Edition, "Mathematics"

Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-B1 "Perform Basic Arithmetic Functions"

Introduction:

Many operations which the machinist must perform require the location of holes or other machining locations from a datum or origin point. Many drawings are dimensioned such that part features must be located in reference to another point or part feature. Many of today's machine tools have been fitted with digital read-out equipment which allow the machinist to quickly set and move to the required machining locations. Virtually all of the CNC machines in use today require that the machinist be able to locate and program machining locations using the Cartesian coordinate or the polar coordinate systems. It is, therefore, imperative that the machinist understand and be able to use these coordinate systems.

Presentation Outline:

- I. Identify Points Using the Cartesian Coordinate System
  - A. Describe the Cartesian (rectangular) coordinate system - the basis for all machine movement
    - 1. Define *axis* - any direction of movement on a machine tool. The spindle is always defined as the Z axis on 3 axis systems.
    - 2. Discuss the plus and minus aspects of an axis
    - 3. Discuss the quadrants I, II, III, and IV. Note that the signs for the X- and Y-axes change for the different quadrants.
    - 4. Discuss the concept of three dimensional locations
    - 5. Discuss how points are described in both 2- and 3-axis systems
    - 6. Describe how a part fits into the axis system
- II. Identify Points Using the Polar Coordinate System
  - A. Describe the *polar coordinate system* - a system by which all points are located around a known location (or pole).
    - 1. Points are usually identified by a known distance from the pole and a given angle from the horizontal (3:00 o'clock position equals zero degrees)
    - 2. Positive angles are measured from angle zero in a counterclockwise direction
    - 3. Negative angles are measured from angle zero in a clockwise direction
  - B. Student practice
- III. Locate Points Using the Absolute Dimensioning System
  - A. Define *absolute positioning*- in absolute positioning, all machine locations are taken from one fixed zero (origin) point. This origin point does not change.
  - B. This corresponds to the datum dimensioning method used by drafters. In datum dimensioning, all dimensions on a drawing are placed in reference to one fixed zero point.
  - C. Student practice
- IV. Locate Points Using the Incremental Dimensioning System
  - A. Define *incremental positioning*- in incremental positioning, the X0/Y0 moves with each position change. The current position, in fact, becomes the X0/Y0 for the next positioning move.
  - B. This corresponds to the delta dimensioning method used by drafters. In delta dimensioning, all dimensions on a drawing are "chain-linked." Each location is dimensioned from the previous one.
  - C. Student practice

Practical Application:

Students will be able to calculate boring and cutting patterns for those machines which use datum-point controls.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-C1) dealing with the identification of basic layout of drawings.

CNC-B8-HO
Use Coordinate Systems
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:
- a. Identify points using the Cartesian coordinate system;
- b. Identify points using the absolute dimensioning system;
- c. Identify points using the incremental dimensioning system; and,
- d. Identify points using the polar coordinate system.

Module Outline:

I. Identify Points Using the Cartesian Coordinate System
  A. Describe the Cartesian (rectangular) coordinate system - the basis for all machine movement
    1. Define *axis* - any direction of movement on a machine tool. The spindle is always defined as the Z axis on 3 axis systems.
    2. Discuss the plus and minus aspects of an axis
    3. Discuss the quadrants I, II, III, and IV. Note that the signs for the X- and Y-axes change for the different quadrants.
    4. Discuss the concept of three dimensional locations
    5. Discuss how points are described in both 2- and 3-axis systems
    6. Describe how a part fits into the axis system

II. Identify Points Using the Polar Coordinate System
  A. Describe the *polar coordinate system* - a system by which all points are located around a known location (or pole).
    1. Points are usually identified by a known distance from the pole and a given angle from the horizontal (3:00 o'clock position equals zero degrees)
    2. Positive angles are measured from angle zero in a counterclockwise direction
    3. Negative angles are measured from angle zero in a clockwise direction
  B. Student practice

III. Locate Points Using the Absolute Dimensioning System
  A. Define *absolute positioning*- in absolute positioning, all machine locations are taken from one fixed zero (origin) point. This origin point does not change.
  B. This corresponds to the datum dimensioning method used by drafters. In datum dimensioning, all dimensions on a drawing are placed in reference to one fixed zero point.
  C. Student practice

IV. Locate Points Using the Incremental Dimensioning System
   A. Define *incremental positioning*- in incremental positioning, the X0/Y0 moves with each position change. The current position, in fact, becomes the X0/Y0 for the next positioning move.
   B. This corresponds to the delta dimensioning method used by drafters. In delta dimensioning, all dimensions on a drawing are "chain-linked." Each location is dimensioned from the previous one.
   C. Student practice

Name____________________________ Date________________

CNC-B8
Use Coordinate Systems
Self-Assessment

Circle the letter preceding the correct answer.

1. Using the Cartesian plane shown (Diagram 1), what can be said of point 1, regardless of the values of the actual coordinates?
   A. X is positive and Y is positive.
   B. X is positive and Y is negative.
   C. X is negative and Y is positive.
   D. X is negative and Y is negative.
   E. None of the above answers is correct.

2. Using Diagram 1, what can be said of point 2, regardless of the actual values of the coordinates?
   A. X is positive and Y is positive.
   B. X is positive and Y is negative.
   C. X is negative and Y is positive.
   D. X is negative and Y is negative.
   E. None of the above answers is correct.

3. Which of the following statements is **not** true?
   A. In absolute dimensioning, all machine locations are taken from a point called the *origin* or *zero point*.
   B. The origin point is fixed.
   C. Absolute dimensioning corresponds the drafting method known as *datum dimensioning*.
   D. In datum dimensioning, all dimensions are determined from a single, fixed point.
   E. All of the above statements are true.

4. Incremental positioning:
   A. Corresponds to the drafting method known as *delta dimensioning*.
   B. Moves the X0/Y0 point after each operation.
   C. Has "chain-linked" dimensions on the blueprints.
   D. All of the above answers are applicable to the question.
   E. None of the above answers is correct.

5. In a three-axis system, the spindle always corresponds to the:
   - A. X-axis.
   - B. Y-axis.
   - C. Z-axis.
   - D. The correspondence of the spindle is not standard.
   - E. None of the above answers is correct.

6. In the *polar coordinate* system, points are identified by a known distance from the pole and a known ___ from the horizon.
   - A. Angle
   - B. 3:00 o'clock position
   - C. Horizon
   - D. Pole
   - E. None of the above answers is correct.

For questions 7 through 9, all holes are 3/8 inch diameter and the workpiece setup point corresponds to a point of 6,4 from the table origin.

7. Using Diagram 2 and the absolute dimensioning system, dimension program the part. Show all work. All measurements are in inches.

Hole	X	Y
A		
B		
C		

8. Using Diagram 2 and the incremental dimensioning system, dimension program the part. Show all work. All measurements are in inches.

Hole	X	Y
A		
B		
C		

9. Using Diagram 3 and the absolute dimensioning system, dimension program the part. Show all work; all linear measurements are in inches.

Hole	X	Y
A		
B		
C		
D		
E		

10. Using Diagram 3 and the incremental dimensioning system, dimension program the part. Show all work; all linear measurements are in inches.

Hole	X	Y
A		
B		
C		
D		
E		

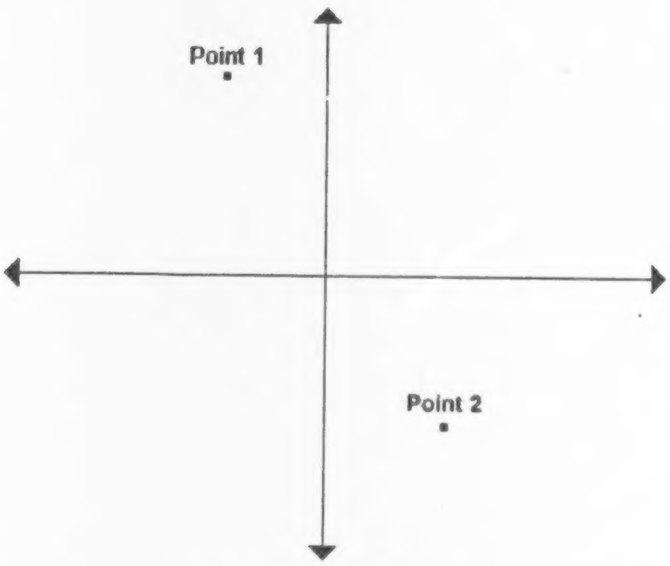
Point 1
Point 2

Diagram 1 - CNC-B8

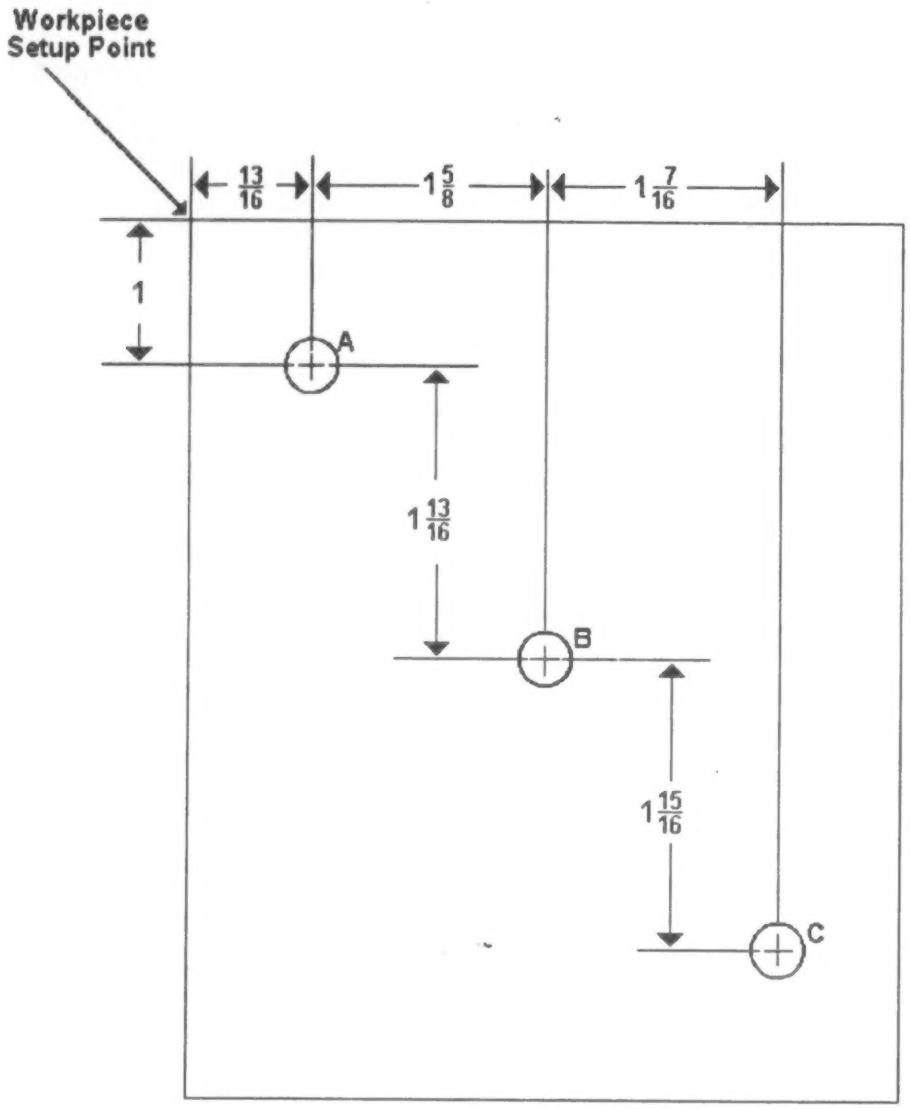
Workpiece
Setup Point
13/16
1 5/8
1 7/16
1
A
1 13/16
B
1 15/16
C

Diagram 2 - CNC-B8

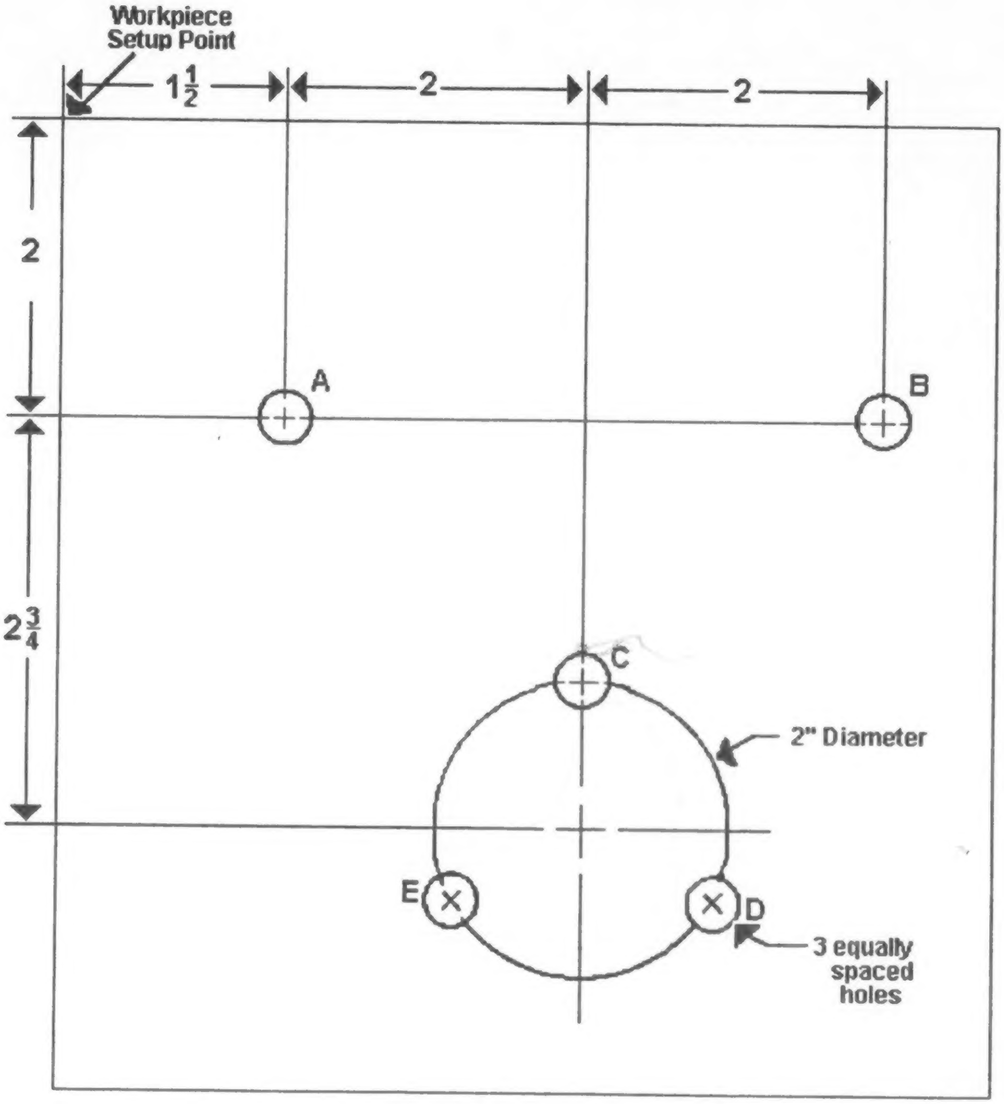
Workpiece Setup Point
1 1/2
2
2
2
2 3/4
A
B
C
2" Diameter
E
D
3 equally spaced holes

Diagram 3 - CNC-B8

CNC-B8
Use Coordinate Systems
Self-Assessment Answer Key

1. C
2. D
3. E
4. D
5. C
6. A
7.

Hole	X	Y
A	6 13/16	3
B	8 7/16	1 3/16
C	9 7/8	-3/4

8.

Hole	X	Y
A	6 13/16	3
B	1 5/8	-1 13/16
C	1 7/16	-1 15/16

9.

Hole	X	Y
A	7 ½	2
B	11 ½	2
C	9 ½	1/4
D	10 23/64	-1 1/4
E	8 37/64	-1 1/4

10.

Hole	X	Y
A	7 ½	2
B	4	0
C	-2	-1 3/4
D	55/64	-1 ½
E	-1 23/32	0

CNC MACHINIST .... programs, edits, sets up, and operates CNC lathes, mills and grinders to perform machining operations necessary to produce workpieces to referenced engineering standards.

	Duties	← Tasks →												
A	**Practice Safety**	A-1 Follow safety manuals and all safety regulations/ requirements	A-2 Use protective equipment	A-3 Follow safe operating procedures for hand and machine tools	A-4 Maintain a clean and safe work environment	A-5 MSDS/ control chemical hazards								
B	**Apply Mathematical Concepts**	B-1 Perform basic arithmetic functions	B-2 Convert fractions/ decimals	B-3 Convert Metric/ English measurements	B-4 Perform basic algebraic operations	B-5 Use practical geometry	B-6 Understand basic trigonometry	B-7 Calculate speeds and feeds for machining	B-8 Use coordinate systems					
C	**Interpret Engineering Drawings and Control Documents**	C-1 Identify basic layout of drawings	C-2 Identify basic types of drawings	C-3 Review blueprint notes and dimensions	C-4 List the purpose of each type of drawing	C-5 Verify drawing elements	C-6 Practice Geometric Dimensioning and Tolerancing (GD&T)	C-7 Analyze bill of materials (BOM)	C-8 Describe the relationship of engineering drawings to planning	C-9 Understand and use quality systems	C-10 Verify standard requirements			
D	**Recognize Different Manufacturing Materials and Processes**	D-1 Identify materials with desired properties	D-2 Identify materials and processes to produce a part	D-3 Describe the heat treating process	D-4 Test metal samples for hardness	D-5 Understand welding operations								
E	**Measure/ Inspect**	E-1 Understand metrology terms	E-2 Select measurement tools	E-3 Measure with hand held instruments	E-4 Eliminate measurement variables	E-5 Measure/ inspect using surface plate and accessories	E-6 Inspect using stationary equipment							
F	**Perform Conventional Machining**	F-1 Prepare and plan for machining operations	F-2 Use hand tools	F-3 Operate power saws	F-4 Operate drill presses	F-5 Operate vertical milling machines	F-6 Operate horizontal milling machines	F-7 Operate metal cutting lathes	F-8 Operate grinding/ abrasive machines					
G	**Perform Advanced Machining**	G-1 Understand CNC basics	G-2 Program CNC machines	G-3 Operate CNC machining centers (mills)	G-4 Operate CNC turning centers (lathes)									
H	**Use Verification and Communication Systems**	H-1 Use personal computer	H-2 Use various operating systems	H-3 Use computer communications systems	H-4 Use verification systems	H-5 Use the Internet								
I	**Program Using CAM System**	I-1 Understand CAD/ CAM programs	I-2 Manipulate CAD functions	I-3 Process simple tool-path data	I-4 Create advanced surface models	I-5 Process complex tool-path functions								

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-C1

Subject: **Advanced CNC and CAM** **Time: 12 Hrs.**

Duty: **Interpret Engineering Drawings and Control Documents**
Task: Identify Basic Layout of Drawings

Objective(s):

Upon completion of this unit the student will be able to:
a. Identify types of lines within a drawing;
b. List the essential components found in the title block;
c. Locate bill of materials in a drawing; and,
d. List the components found in the revision block.

Instructional Materials:

MASTER Handouts (CNC-C1-HO) (two)
MASTER Self-Assessment
Sample drawings with matching parts
Orthographic projection box

References:

How to Read Shop Prints and Drawings, William E. Hardman, National Tooling & Machining Association, Latest Edition, "Introduction to Shop Prints"

Technical Drawing, Giesecke, Mitchell, Spencer, Hill, Dygdon, and Novak, MacMillan Publishing, Latest Edition, "Design and Working Drawings"

Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition, "Reading Drawings"

Student Preparation:

Introduction:

One of the most critical skills that a machinist develops is that of reading blueprints. This skill forms the basis of virtually all decision-making in the workplace because the blueprint is the master document governing the operation. At first look, blueprints may seem to be written in some alien language. With practice, however, the machinist soon becomes capable of reading blueprints almost at a glance. Familiarity with the lines and conventions of drafting is all that is required.

Presentation Outline:

I. Identify Types of Lines Within a Drawing
  A. Break
    1. **Short**: a generally freehand, heavy, wavy line; indicating that the part is continuous and unchanged between the lines
      a. Square break
      b. Solid, round break
      c. Hollow, round break
    2. **Long**: a thin line broken by zig-zags indicating that the part is continuous and unchanged between the lines
  B. Center Lines
    1. A thin, broken line composed of alternating long and short lines, evenly spaced
    2. Uses
      a. To show the center of a circle, arc, or part
      b. To show that a part is bilaterally symmetrical. Used in conjunction with three parallel lines at each end
      c. To indicate motion in conjunction with phantom lines
  C. Cutting Plane
    1. A heavy, broken line whose ends, which have arrowheads pointed in the direction of the drawing, are perpendicular to the body of the line. Sometimes shown as one long and two short alternating lines.
    2. To indicate an imaginary cut through a piece; this line may be offset
  D. Dimension Lines
    1. Thin, solid lines having arrowheads at both ends. The center is left open for dimensional specifics.
    2. Show the size of the piece relative to the line's direction
  E. Extension Lines
    1. Thin, solid lines visibly removed from the edge to which they refer
    2. Used in conjunction with dimensions lines to show the sizes of objects
  F. Hidden (Invisible) Lines
    1. Thin, evenly broken line
    2. Used to delineate any feature not visible in the particular view
  G. Leader

1. Thin, solid line with one arrowhead (when ending on an edge) or a dot (when ending on a surface) at one end and a bend that changes the line's direction at the other
2. To annotate the drawing

H. Object (Visible) Lines
1. Very heavy, solid lines
2. Demarcates edges, surfaces, and corners in the visible view

I. Phantom Lines
1. Thin line composed of one long and two short, equally spaced parts
2. Uses
   a. Indicate alternate positions
   b. Demonstrate mating surfaces
   c. Show repetitious details

J. Screw Threads
1. Three methods
   a. Actual drawing (seldom used)
   b. Schematic representation
   c. Simplified representation
2. To display threading on parts. When marked with a "B" indicates a bore or internal thread.

K. Section
1. Thin, solid lines, usually at a definite angle to the horizontal
2. To indicate that the view has been cut off from the main part or that the part has been cut in two
3. Sometimes used to identify specific materials

J. Precedence of Lines: On occasion, lines in a drawing may be superimposed. When this occurs, the lines are shown in the following order; e.g., visible lines are shown instead of any others; etc.
1. Visible (Object) line
2. Hidden (Invisible) line
3. Cutting plane line
4. Center line
5. When either a visible or a hidden line occludes a center line, the ends of the center line are detached from the *outside* edge of the part

II. List the Essential Components Found in the Title Block--note That Title Blocks Are Not Fully Standardized and That Their Contents May Vary from Company to Company

A. The title block is usually found in the lower right-hand corner.

B. Components
1. Name and address of the manufacturer or designer
2. *Title* or brief description of parts
3. *Part Number* identifying the specific part

    4. *Drawing Number* identifying the specific *drawing*
    5. *Drawn by/Date* shows the drafter and the date of the drawing's completion
    6. *Checked by/Date* shows the drawing's inspector and the date of approval
    7. *Replaces* lists a part number that the new part will supersede
    8. *Replaced by* lists a part that supersedes the part in the drawing. If the drawing is the most current, there will be a slash through this block.
    9. *Scale* shows the proportion of the drawing to life
        a. *Full* indicates that the drawing is life-sized
        b. *Half* indicates that the drawing is one-half life size *in each dimension*
    10. *Page* shows both the current page, *p*, and the total number of pages, *t*, in this format: *p of t*
    11. *Tolerances* show the size limits of dimensions that are not specifically dimensioned in the drawing. These general tolerances are always secondary to tolerances listed in the drawing
    12. *Heat Treatment* shows the required heat treatment and hardness specifications. If there are no specifications, then the box says NONE.
    13. *Material* shows the exact material from which the part must be made
    14. *Finish* indicates the general surface finish of the completed part
    15. *Code Identification Number* identifies the specific manufacturer or design group. The number is provided by the Federal Government.
    16. *Size* shows the physical size of the draft paper
    17. The word NOTED in any block means that the information is supplied in the body of the drawing at or near the relevant item

III. Locate Bill of Materials in a Drawing: The Materials List Is Usually Located Immediately above the Title Block.

IV. List the Components Found in the Revision Block
  A. *Zone* refers to area which is to be changed. Large drawings generally have an alphanumeric coordinate system for clarity.
  B. *Revision* specifies the exact change in the part. It is identified by a letter.
  C. *Description* contains a brief description of the revision
  D. *Date* is the effective date of the revision
  E. *Apvd* abbreviates Approved. This is the identification of the inspector who approved the changes.

Practical Application:

The student will be able to identify the basic components of the title block and other notation blocks on a blueprint, as well as recognizing the various lines and their applications.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-C2) dealing with the different types of drawings used in the machine shop.

CNC-C1-HO1
Identify Basic Layout of Drawings
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:
- a. Identify types of lines within a drawing;
- b. List the essential components found in the title block;
- c. Locate bill of materials in a drawing; and,
- d. List the components found in the revision block.

Module Outline:

- I. Identify Types of Lines Within a Drawing
  - A. Break
    - 1. **Short**: a generally freehand, heavy, wavy line; indicating that the part is continuous and unchanged between the lines
      - a. Square break
      - b. Solid, round break
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    - 2. **Long**: a thin line broken by zig-zags indicating that the part is continuous and unchanged between the lines
  - B. Center Lines
    - 1. A thin, broken line composed of alternating long and short lines, evenly spaced
    - 2. Uses
      - a. To show the center of a circle, arc, or part
      - b. To show that a part is bilaterally symmetrical. Used in conjunction with three parallel lines at each end
      - c. To indicate motion in conjunction with phantom lines
  - C. Cutting Plane
    - 1. A heavy, broken line whose ends, which have arrowheads pointed in the direction of the drawing, are perpendicular to the body of the line. Sometimes shown as one long and two short alternating lines.
    - 2. To indicate an imaginary cut through a piece; this line may be offset
  - D. Dimension Lines
    - 1. Thin, solid lines having arrowheads at both ends. The center is left open for dimensional specifics.
    - 2. Show the size of the piece relative to the line's direction
  - E. Extension Lines

    1. Thin, solid lines visibly removed from the edge to which they refer
    2. Used in conjunction with dimensions lines to show the sizes of objects
- F. Hidden (Invisible) Lines
    1. Thin, evenly broken line
    2. Used to delineate any feature not visible in the particular view
- G. Leader
    1. Thin, solid line with one arrowhead (when ending on an edge) or a dot (when ending on a surface) at one end and a bend that changes the line's direction at the other
    2. To annotate the drawing
- H. Object (Visible) Lines
    1. Very heavy, solid lines
    2. Demarcates edges, surfaces, and corners in the visible view
- I. Phantom Lines
    1. Thin line composed of one long and two short, equally spaced parts
    2. Uses
        a. Indicate alternate positions
        b. Demonstrate mating surfaces
        c. Show repetitious details
- J. Screw Threads
    1. Three methods
        a. Actual drawing (seldom used)
        b. Schematic representation
        c. Simplified representation
    2. To display threading on parts. When marked with a "B" indicates a bore or internal thread.
- K. Section
    1. Thin, solid lines, usually at a definite angle to the horizontal
    2. To indicate that the view has been cut off from the main part or that the part has been cut in two
    3. Sometimes used to identify specific materials
- J. Precedence of Lines: On occasion, lines in a drawing may be superimposed. When this occurs, the lines are shown in the following order; e.g., visible lines are shown instead of any others; etc.
    1. Visible (Object) line
    2. Hidden (Invisible) line
    3. Cutting plane line
    4. Center line
    5. When either a visible or a hidden line occludes a center line, the ends of the center line are detached from the *outside* edge of the part

II. List the Essential Components Found in the Title Block--note That Title Blocks Are Not Fully Standardized and That Their Contents May Vary from Company to Company

A. The title block is usually found in the lower right-hand corner.

B. Components

1. Name and address of the manufacturer or designer
2. *Title* or brief description of parts
3. *Part Number* identifying the specific part
4. *Drawing Number* identifying the specific *drawing*
5. *Drawn by/Date* shows the drafter and the date of the drawing's completion
6. *Checked by/Date* shows the drawing's inspector and the date of approval
7. *Replaces* lists a part number that the new part will supersede
8. *Replaced by* lists a part that supersedes the part in the drawing. If the drawing is the most current, there will be a slash through this block.
9. *Scale* shows the proportion of the drawing to life
   a. *Full* indicates that the drawing is life-sized
   b. *Half* indicates that the drawing is one-half life size *in each dimension*
10. *Page* shows both the current page, *p*, and the total number of pages, *t*, in this format: *p of t*
11. *Tolerances* show the size limits of dimensions that are not specifically dimensioned in the drawing. These general tolerances are always secondary to tolerances listed in the drawing
12. *Heat Treatment* shows the required heat treatment and hardness specifications. If there are no specifications, then the box says NONE.
13. *Material* shows the exact material from which the part must be made
14. *Finish* indicates the general surface finish of the completed part
15. *Code Identification Number* identifies the specific manufacturer or design group. The number is provided by the Federal Government.
16. *Size* shows the physical size of the draft paper
17. The word NOTED in any block means that the information is supplied in the body of the drawing at or near the relevant item

III. Locate Bill of Materials in a Drawing: The Materials List Is Usually Located Immediately above the Title Block.

IV. List the Components Found in the Revision Block

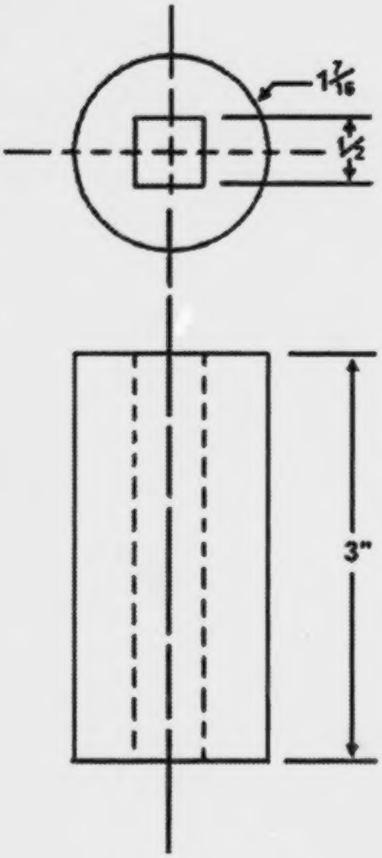
A. *Zone* refers to area which is to be changed. Large drawings generally have an alphanumeric coordinate system for clarity.

B. *Revision* specifies the exact change in the part. It is identified by a letter.
C. *Description* contains a brief description of the revision
D. *Date* is the effective date of the revision
E. *Apvd* abbreviates Approved. This is the identification of the inspector who approved the changes.

CNC-C1-HO2

Identify Basic Layout of Drawings

Attachment 2: **MASTER** Handout



SQUARE HOLE IN A ROUND PEG			
PART NO.	1010106	DRAWING NO.	A1576B
CHECKED BY	R. van Rijn	10/31/97	
REPLACES	A. Rand	11/14/97	
SCALE	1010071	REPLACED BY	——
TOLERANCES	±1/64	PAGE	1 of 1
MATERIAL	Plutonium	FINISH	RMS

Name____________________________ Date________________

CNC-C1
Identify Basic Layout of Drawings
Self-Assessment

Identify the following lines:

1. Place the proper letter in front of each of the descriptions that best describe the line.

(A). BREAK LINE SHORT
(B). BREAK LINE LONG
(C). CENTER LINES
(D). CUTTING PLANE LINES
(E). DIMENSION LINES
(F). EXTENSION LINES
(G). HIDDEN LINES (INVISIBLE)
(H). LEADER LINES
(I). OBJECT LINES (VISIBLE)
(J). PHANTOM LINES
(K). SECTION LINES

( ). Thin, solid lines, usually at a definite angle to the horizontal.

( ). Thin line composed of one long and two short, equally spaced, parts.

( ). Very heavy, solid lines.

( ). A heavy, broken line whose ends, which have arrowheads pointed in the direction of the drawing, are perpendicular to the body of the line. Sometimes shown as one long and two short alternating lines.

( ). Thin, solid lines having arrowheads at both ends. The center is left open.

( ). Thin, solid lines visibly removed from the edge to which they refer.

( ). Thin, even broken line.

( ). Thin, solid line with one arrowhead (when ending on an edge) or a dot (when ending on a surface) at one end and a bend that changes the line's direction at the other.

CNC-C1

Identify Basic Layout of Drawings

Self-Assessment

1. K.

   J.

   I.

   D.

   E.

   F.

   G.

   H.

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-C2

Subject: **Advanced CNC and CAM** **Time: 4 Hrs.**

Duty: **Interpret Engineering Drawings and Control Documents**
Task: Identify Basic Types of Drawings

Objective(s):

Upon completion of this unit the student will be able to:
a. Identify orthographic views;
b. Identify positions of views (top, front, side, and auxiliary);
c. Visualize one or more views from a given view;
d. Identify isometric views;
e. Identify exploded isometric drawings; and,
f. Identify assembly drawings.

Instructional Materials:

MASTER Handout (CNC-C2-HO)
MASTER Self-Assessment
Several prints showing each of the above views
Parts corresponding to the drawings used

References:

How to Read Shop Prints and Drawings, William E. Hardman, National Tooling & Machining Association, Latest Edition, “Introduction to Shop Prints & Lines and Their Uses in Orthographic Projections”
Technical Drawing, Giesecke, Mitchell, Spencer, Hill, Dygdon, and Novak, MacMillan Publishing, Latest Edition, “Axonometric Projections”
Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition, “Reading Drawings”
Machinery’s Handbook, Industrial Press, Latest Edition

Student Preparation:

Students should have previously completed the following Technical Modules:
CNC-C1 “Identify Basic Layout of Drawings”

Introduction:

Blueprints come in many forms. Although most of them are orthographic, a large number of them are done in other perspectives since the orthographic view is not always the best-suited to the manufacture of a specific part. Other projections aid in visualizing the final part, and allow the technician to see the workpiece before it is actually made.

Presentation Outline:

I. Identify Orthographic Views
    A. Characteristics of orthography: all views perpendicular to the viewer; no vanishing points
    B. Review the *projection planes*
II. Identify Positions of Views
    A. Top
    B. Front
    C. Side
    D. Auxiliary
III. Visualize One or More Views from a Given Angle
IV. Identify Isometric Views: All Angles at the Reference Origin Are 120°
V. Identify Exploded Isometric Drawings
VI. Identify Assembly Drawings

Practical Application:

Students shall be able to identify all views and projections covered in this module and to discuss their purposes and uses.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-C3) dealing with blueprint notes and dimensions.

CNC-C2-HO
Identify Basic Types of Drawings
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Identify orthographic views;
b. Identify positions of views (top, front, side, and auxiliary);
c. Visualize one or more views from a given view;
d. Identify isometric views;
e. Identify exploded isometric drawings; and,
f. Identify assembly drawings.

Module Outline:

I. Identify Orthographic Views
    A. Characteristics of orthography: all views perpendicular to the viewer; no vanishing points
    B. Review the *projection planes*
II. Identify Positions of Views
    A. Top
    B. Front
    C. Side
    D. Auxiliary
III. Visualize One or More Views from a Given Angle
IV. Identify Isometric Views; All Angles at the Reference Origin Are 120°
V. Identify Exploded Isometric Drawings
VI. Identify Assembly Drawings

Name____________________________ Date________________

CNC-C2
Identify Basic Types of Drawings
Self-Assessment

Circle the letter preceding the correct answer.

1. What is the main purpose of isometric drawings?
   - A. To render an object in three dimensions
   - B. To show the relationship of the parts more clearly
   - C. To demonstrate the finish of the part
   - D. To relieve the stress on drafters
   - E. None of the above answers is correct.

2. What is the main purpose of exploded isometric drawings?
   - A. To render an object in three dimensions
   - B. To show the relationship of the parts more clearly
   - C. To demonstrate the finish of the part
   - D. To relieve the stress on drafters
   - E. None of the above answers is correct.

3. Which of the following is characteristic of *orthographic* projection?
   - A. All views are perpendicular to the drafter
   - B. All angles are 120° around a central axis
   - C. Two vanishing points
   - D. One axis parallel to the plane of the drawing
   - E. None of the above answers is correct.

4. Which of the following is characteristic of *isometric* projection?
   - A. All views are perpendicular to the drafter
   - B. All angles are 120° around a central axis
   - C. Two vanishing points
   - D. One axis parallel to the plane of the drawing
   - E. None of the above answers is correct.

5. Which of the following is characteristic of *oblique* projection?
   - A. All views are perpendicular to the drafter
   - B. All angles are 120° around a central axis
   - C. Two vanishing points
   - D. One axis parallel to the plane of the drawing
   - E. None of the above answers is correct.

6. In the United States, most orthographic drawings are _____ angle projections.
   - A. First
   - B. Second
   - C. Third
   - D. Fourth
   - E. None of the above answers is correct.

7. Europeans usually use the _____ angle projection.
   - A. First
   - B. Second
   - C. Third
   - D. Fourth
   - E. None of the above answers is correct.

8. First angle projections are _____, relative to the viewer.
   - A. Upside-down
   - B. Mirror-imaged
   - C. Both A and B are correct.
   - D. None of the above answers is correct.

9. The international projection symbols show:
   - A. Which angle of projection is used.
   - B. How many projections are in the drawing.
   - C. Whether a drawing is isometric or oblique.
   - D. The nation of the drawing's origin.
   - E. None of the above answers is correct.

10. An auxiliary view shows:
    - A. Inclined surfaces that cannot be clearly shown on a principal view.
    - B. The position and relationship of the parts in an assembly.
    - C. The complete depth of the part, with 45° vanishing angles.
    - D. All of the above answers are correct.
    - E. None of the above answers is correct.

CNC-C2
Identify Basic Types of Drawings
Self-Assessment Answer Key

1. A
2. B
3. A
4. B
5. D
6. C
7. A
8. C
9. A
10. A

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-C3

Subject: **Advanced CNC anc CAM** **Time: 12 Hrs.**

Duty: **Interpret Engineering Drawings and Control Documents**
Task: Review Blueprint Notes and Dimensions

Objective(s):

Upon completion of this unit the student will be able to:

a. Explain basic blueprint terminology;
b. Identify the types of dimensions;
c. Identify general note symbols;
d. Locate notes on a print;
e. Interpret commonly used abbreviations and terminology;
f. Determine tolerances associated with dimensions on a drawing;
g. Determine the tolerance for a reference dimension;
h. Determine the surface finish for a given part; and,
i. List the essential components found in the general drawing notes.

Instructional Materials:

MASTER Handout (CNC-C3-HO)
MASTER Self-Assessment
Several drawings with various projects
Parts corresponding to the selected drawings

References:

How to Read Shop Prints and Drawings, William E. Hardman, National Tooling & Machining Association, Latest Edition, "Introduction to Shop Prints & Lines and Their Uses in Orthographic Projections"
Technical Drawing, Giesecke, Mitchell, Spencer, Hill, Dygdon, and Novak, MacMillan Publishing, Latest Edition, "Axonometric Projections"
Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition, "Reading Drawings"

Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-C1 "Identify Basic Layout of Drawings"
CNC-C2 "Identify Basic Types of Drawings"

Introduction:

Of all the skills necessary to a successful career as a machinist, one of the most basic and most important is the ability to read and interpret blueprints and other designs. Without such knowledge, the machinist is completely lost, unable to produce even the simplest parts correctly. The correct interpretation of prints, regardless of whether they are called blueprints, white prints, or something else; requires more than knowledge of lines. The machinist must also thoroughly comprehend the written components of the print.

Presentation Outline:

- I. Explain Basic Blueprint Terminology
  - A. Print Definitions
    - 1. **Print**: an exact copy of an engineering drawing
    - 2. **Engineering drawing:** the original design of anything as drawn by the drafter
  - B. Print Parts and Terms
    - 1. **Title Block**: an area for the controlling information of a document, usually set apart in the lower right-hand corner
    - 2. **Print Body**: the actual drawing of the item, normally consisting of several views
    - 3. **View**: the angle of observation of the artist, usually the top, front, and right side of the item
    - 4. Projections
      - a. **Orthographic**: all views are perpendicular to the drafter's field of vision, lacks vanishing points
      - b. **Isometric**: built around a central point whose radiant axes are equally spaced at 120°
      - c. Other **Axonometric** Views: briefly discuss other views, such as diametric
    - 5. Angles of Projection
      - a. **First Angle Projections** are usually European and SI
      - b. **Third Angle Projections** are North American and either SI or SAE
- II. Identify the Types of Dimensions
  - A. Physical Dimensions
    - 1. **Linear** dimensions show height, width, and length as direction along a straight line
    - 2. **Angular** dimensions display the sizes of angular features
      - a. **Angle of the arc** is size of the actual angle, usually in degrees

      - b. **Length of the arc** measures the size of a rounded feature along the rounded edge. This is usually a reference dimension.
      - c. **Length of the chord** is the direct distance between the end points of the arc
    - 3. **Radial dimensions** display the size of radii (the plural of radius). Discuss *shortened radii* and *true* and *spherical radii.*
    - 4. **Coordinate dimensions** all begin at a particular point known as a *datum point*
      - a. **Rectangular** coordinate dimensions start at some arbitrary datum point 0,0 and are noted in a Cartesian plane
      - b. **Polar** coordinate dimensions start at some arbitrary datum point 0,0 and are noted in lengths of radii and angles of arcs
    - 5. **Tabular** dimensions establish a table of references with a key that is tied to a drawing. This method reduces confusion by eliminating clutter in the body of the drawing.
  - B. Engineering Dimensions Conventions
    - 1. Usually placed in the area that best shows the feature
    - 2. Use of *dimension lines, leader lines,* and *extension lines*
    - 3. **Working** dimensions are those used to control the size of the part
    - 4. **Reference** dimensions are those used to contribute useful, but not essential, information to the machinist
    - 5. **In-process** dimensions show the size of the part after a specific machine process, such as milling, but not the final size of the part. These dimensions are noted as such.
    - 6. **Scale** shows the size of the drawing relative to the size of the part
    - 7. **Tolerances** may be in the title block or noted in the drawing
  - C. Placement of Dimensions
    - 1. **Chaining** shows the relationships between the details of features in a series; sometimes called *incremental dimensioning*
    - 2. **Datum** dimensioning shows the details of features in relation to an arbitrary datum point 0,0; also called *absolute* or *base-line* dimensioning
    - 3. **Direct** dimensioning shows the relationship between two features where that relationship is completely independent of the rest of the part
- III. Identify General Note Symbols
- IV. Identify item number symbols
  - A. Angular symbols
    - 1. ° indicates degrees

2. ' indicates minutes
3. " indicates seconds
4. D or DIA indicates diameter
5. R or RAD indicates radius

B. Linear symbols
1. ' indicates feet
2. " indicates inches
3. Metric linear abbreviations are not symbolic; they are alphabetical abbreviations. Discuss mm, cm, etc.

V. Locate Notes on a Print
A. Dimensional: give specific values to sizes. Discuss conventions on *dual unit dimensioning.*
B. Process
C. Detail
D. Single-view
E. Thickness

VI. Interpret Commonly Used Abbreviations and Terminology

VII. Determine Tolerances Associated with Dimensions on a Drawing
A. Discuss the differences in *standard* or *customary* tolerances and *specific* tolerances
B. Discuss linear tolerance and radial tolerance

VIII. Determine the Tolerance for a Reference Dimension

IX. Determine the Surface Finish for a Given Part
A. Definitions
1. **Roughness**: the fine, irregular ridges/troughs caused by the finishing machine
2. **Waviness**: the large, irregular ridges/troughs caused by the finishing machine. Roughness rides the surface of waviness.
3. **Lay**: the predominant direction of the marks in the surface finish
4. **Waviness Spacing:** the distance between the peaks of two adjacent ridges in the waviness
5. **Waviness Height:** measured within a single waviness spacing, specifies the distance between the higher peak and the bottom of the trough
6. **Roughness Spacing:** similar to waviness spacing, the distance between two adjacent peaks in the waviness
7. **Roughness Sampling Length:** the length of an arbitrary sample of the roughness, used to determine the roughness average
8. **Roughness Average:** the mathematical average of the roughness of a surface within a *roughness sampling length*, measured from a center line and measured in micro inches
9. Lay Symbols:

        a. **Angular lay:** lay runs in two mutually perpendicular directions that are set at an angle that is oblique to the reference line
        b. **Circular lay:** lay is basically circular around the center of the surface
        c. **Multi-directional lay:** lay has no predominant direction
        d. **Parallel lay:** lay is parallel to the reference line
        e. **Particulate lay:** lay has no direction, is protuberant, or particulate
        f. **Perpendicular lay:** lay is perpendicular to the reference line
        g. **Radial lay:** lay is basically radial through the center of the surface
    B. Basic and variant surface texture symbols
        1. Basic checkmark with roughness indicators--maximum only and maximum/minimum values
        2. Finish removal triangular checkmark with removal value
        3. Already finished checkmark with tangential circle
X. List the Essential Components Found in the General Drawing Notes

Practical Application:

All students should be able to look at a simple blueprint and identify all its lines.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-C4) dealing with the purpose of each type of drawing.

CNC-C3-HO
Review Blueprint Notes and Dimensions
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Explain basic blueprint terminology;
b. Identify the types of dimensions;
c. Identify general note symbols;
d. Locate notes on a print;
e. Interpret commonly used abbreviations and terminology;
f. Determine tolerances associated with dimensions on a drawing;
g. Determine the tolerance for a reference dimension;
h. Determine the surface finish for a given part; and,
i. List the essential components found in the general drawing notes.

Module Outline:

I. Explain Basic Blueprint Terminology
  A. Print Definitions
    1. **Print**: an exact copy of an engineering drawing
    2. **Engineering drawing**: the original design of anything as drawn by the drafter
  B. Print Parts and Terms
    1. **Title Block**: an area for the controlling information of a document, usually set apart in the lower right-hand corner
    2. **Print Body**: the actual drawing of the item, normally consisting of several views
    3. **View**: the angle of observation of the artist, usually the top, front, and right side of the item
    4. Projections
      a. **Orthographic**: all views are perpendicular to the drafter's field of vision, lacks vanishing points
      b. **Isometric**: built around a central point whose radiant axes are equally spaced at 120°
      c. Other **Axonometric** Views: briefly discuss other views, such as diametric
    5. Angles of Projection
      a. **First Angle Projections** are usually European and SI
      b. **Third Angle Projections** are North American and either SI or SAE
II. Identify the Types of Dimensions
  A. Physical Dimensions

    1. **Linear** dimensions show height, width, and length as direction along a straight line
    2. **Angular** dimensions display the sizes of angular features
        a. **Angle of the arc** is size of the actual angle, usually in degrees
        b. **Length of the arc** measures the size of a rounded feature along the rounded edge. This is usually a reference dimension.
        c. **Length of the chord** is the direct distance between the end points of the arc
    3. **Radial dimensions** display the size of radii (the plural of radius). Discuss *shortened radii* and *true* and *spherical radii.*
    4. **Coordinate dimensions** all begin at a particular point known as a *datum point*
        a. **Rectangular** coordinate dimensions start at some arbitrary datum point 0,0 and are noted in a Cartesian plane
        b. **Polar** coordinate dimensions start at some arbitrary datum point 0,0 and are noted in lengths of radii and angles of arcs
    5. **Tabular** dimensions establish a table of references with a key that is tied to a drawing. This method reduces confusion by eliminating clutter in the body of the drawing.

B. Engineering Dimensions Conventions
    1. Usually placed in the area that best shows the feature
    2. Use of *dimension lines, leader lines,* and *extension lines*
    3. **Working** dimensions are those used to control the size of the part
    4. **Reference** dimensions are those used to contribute useful, but not essential, information to the machinist
    5. **In-process** dimensions show the size of the part after a specific machine process, such as milling, but not the final size of the part. These dimensions are noted as such.
    6. **Scale** shows the size of the drawing relative to the size of the part
    7. **Tolerances** may be in the title block or noted in the drawing

C. Placement of Dimensions
    1. **Chaining** shows the relationships between the details of features in a series; sometimes called *incremental dimensioning*
    2. **Datum** dimensioning shows the details of features in relation to an arbitrary datum point 0,0; also called *absolute* or *base-line* dimensioning

3. **Direct** dimensioning shows the relationship between two features where that relationship is completely independent of the rest of the part

III. Identify General Note Symbols

IV. Identify item number symbols

A. Angular symbols

1. ° indicates degrees

2. ' indicates minutes

3. " indicates seconds

4. D or DIA indicates diameter

5. R or RAD indicates radius

B. Linear symbols

1. ' indicates feet

2. " indicates inches

3. Metric linear abbreviations are not symbolic; they are alphabetical abbreviations. Discuss mm, cm, etc.

V. Locate Notes on a Print

A. Dimensional: give specific values to sizes. Discuss conventions on *dual unit dimensioning.*

B. Process

C. Detail

D. Single-view

E. Thickness

VI. Interpret Commonly Used Abbreviations and Terminology

VII. Determine Tolerances Associated with Dimensions on a Drawing

A. Discuss the differences in *standard* or *customary* tolerances and *specific* tolerances

B. Discuss linear tolerance and radial tolerance

VIII. Determine the Tolerance for a Reference Dimension

IX. Determine the Surface Finish for a Given Part

A. Definitions

1. **Roughness**: the fine, irregular ridges/troughs caused by the finishing machine

2. **Waviness**: the large, irregular ridges/troughs caused by the finishing machine. Roughness rides the surface of waviness.

3. **Lay**: the predominant direction of the marks in the surface finish

4. **Waviness Spacing:** the distance between the peaks of two adjacent ridges in the waviness

5. **Waviness Height:** measured within a single waviness spacing, specifies the distance between the higher peak and the bottom of the trough

6. **Roughness Spacing:** similar to waviness spacing, the distance between two adjacent peaks in the waviness

7. **Roughness Sampling Length:** the length of an arbitrary sample of the roughness, used to determine the roughness average
8. **Roughness Average:** the mathematical average of the roughness of a surface within a *roughness sampling length*, measured from a center line and measured in micro inches
9. Lay Symbols:
    a. **Angular lay:** lay runs in two mutually perpendicular directions that are set at an angle that is oblique to the reference line
    b. **Circular lay:** lay is basically circular around the center of the surface
    c. **Multi-directional lay:** lay has no predominant direction
    d. **Parallel lay:** lay is parallel to the reference line
    e. **Particulate lay:** lay has no direction, is protuberant, or particulate
    f. **Perpendicular lay:** lay is perpendicular to the reference line
    g. **Radial lay:** lay is basically radial through the center of the surface

B. Basic and variant surface texture symbols
1. Basic checkmark with roughness indicators--maximum only and maximum/minimum values
2. Finish removal triangular checkmark with removal value
3. Already finished checkmark with tangential circle

X. List the Essential Components Found in the General Drawing Notes

Name______________________________ Date________________

CNC-C3
Review Blueprint Notes and Dimensions
Self-Assessment

Circle the letter preceding the correct answer.

1. ___ dimensions show length, width, and height as straight lines.
   A. Angular
   B. Linear
   C. Radial
   D. All of the above answers are correct.
   E. None of the above answers is correct.

2. What is meant by *circular lay?*
   A. The pattern of the finish is not parallel to the sides of the piece.
   B. The pattern of the finish is not parallel to anything.
   C. The pattern of the finish is roughly circular.
   D. All of the above answers are correct.
   E. None of the above answers is correct.

3. In ___ projection, all views are perpendicular to the viewer.
   A. Isometric
   B. Orthographic
   C. Oblique
   D. All of the above answers are correct.
   E. None of the above answers is correct.

4. In ___ projection, all views are centered on a particular point with 120° angles.
   A. Isometric
   B. Orthographic
   C. Oblique
   D. All of the above answers are correct.
   E. None of the above answers is correct.

5. The fine, irregular ridges/troughs caused by the finishing machine are called:
   A. Roughness
   B. Waviness
   C. Lay
   D. All of the above answers are correct.
   E. None of the above answers is correct.

6. ___ rides the surface of ___.
   A. Waviness . . . lay
   B. Waviness . . . roughness
   C. Lay . . . waviness
   D. Roughness . . . waviness
   E. None of the above answers is correct.

7. The angle of the arc is:
   A. The size of the actual angle, usually in degrees.
   B. The size of a rounded feature along the rounded edge, usually a reference dimension.
   C. The direct distance between the end points of the arc.
   D. All of the above answers are correct.
   E. None of the above answers is correct.

8. **Chaining** shows the:
   A. Relationships between the details of features in a series.
   B. Details of features in relation to an arbitrary datum point 0,0.
   C. Relationship between two features where that relationship is completely independent of the rest of the part.
   D. All of the above answers are correct.
   E. None of the above answers is correct.

9. **Datum dimensioning** shows the:
   A. Relationships between the details of features in a series.
   B. Details of features in relation to an arbitrary datum point 0,0.
   C. Relationship between two features where that relationship is completely independent of the rest of the part.
   D. All of the above answers are correct.
   E. None of the above answers is correct.

10. In angular dimensioning, the apostrophe (') indicates ___, while the quotation mark (") indicates ___.
   A. Minutes . . . seconds
   B. Seconds . . . minutes
   C. Feet . . . inches
   D. Inches . . . feet
   E. None of the above answers is correct.

CNC-C3
Review Blueprint Notes and Dimensions
Self-Assessment Answer Key

1.	B
2.	C
3.	B
4.	A
5.	A
6.	D
7.	A
8.	A
9.	B
10.	A

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-C4

Subject: **Advanced CNC and CAM** **Time: 8 Hrs.**

Duty: **Interpret Engineering Drawings and Control Documents**
Task: List the Purpose of Each Type of Drawing

Objective(s):

Upon completion of this unit the student will be able to:

a. Identify the purpose of orthographic (3 views) drawings;
b. Identify the purpose of isometric drawing;
c. Identify the purpose of exploded isometric drawing; and,
d. Identify the purpose of assembly drawings.

Instructional Materials:

MASTER Handout (CNC-C4-HO)
MASTER Self-Assessment
Several engineering drawings, with at least one isometric and at least one exploded view
Several assembly drawings

References:

How to Read Shop Prints and Drawings, William E. Hardman, National Tooling & Machining Association, Latest Edition, "Introduction to Shop Prints & Lines and Their Uses in Orthographic Projections"
Technical Drawing, Giesecke, Mitchell, Spencer, Hill, Dygdon, and Novak, MacMillan Publishing, Latest Edition, "Anonometric Projections"
Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition, "Reading Drawings"

Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-C1	"Identify Basic Layout of Drawings"
CNC-C2	"Identify Basic Types of Drawings"
CNC-C3	"Review Blueprint Notes and Dimensions"

Introduction:

Learning the various forms of drawings is the key to a full understanding of blueprints and other engineering drawings.

Presentation Outline:

NB: The Self-Assessment for this module is greatly dependent on the engineering drawings presented. Therefore, the instructor must complete the questions for the Self-Assessment. The editors strongly recommend a minimum of twenty questions for this module.

I. Identify the Purpose of Orthographic Views
  A. Any orthographic drawing must have a minimum of two views in order to show an object completely.
  B. The top view may be referred to as the plan view. The front or side views may be referred to as the elevations views.
II. Identify Positions of Views (Top, Front, Side, and Auxiliary)
  A. Top, is usually to the left and at the top of the print when viewing a single object, and represents the objects top if you were looking down at it.
  B. Front is directly below the top view, and on the same center line as the top. The front does not necessarily mean the actual front of the object.
  C. Side or sometimes referred as the right side is normally the right side of the front view and is on the same center lines as well as the same elevation.
III. Visualize One or More Views from a Given View
  A. In any given view the student can visualize more then one side of a object. The object can be shown in one of many positions.
IV. Identify Isometric Views
  A. Any object can be drawn from four different directions isometrically, but there is usually one view that best shows the object.
  B. When using isometrics the student should be familiar with the isometric axes, and the term preferred north and alternate north.
  C. In the isometric format, the lines of the object remain parallel and the object is drawn about the three isometric axes that are 120° degrees apart which is at 30° from the plane of the drawing.
  D. Isometrics distort dimensions; therefore, you cannot draw isometrics to scale.
V. Identify Exploded Isometric Drawings
  A. An *exploded drawing* is a picture of an assembly of several parts drawn isometrically to show the proper steps in assembling a unit.
VI. Identify Assembly Drawings

A. *Assembly drawings* are drawings in which the various parts of an object are shown in their relative positions in the completed unit.

B. Assembly drawings are also used:
   1. To illustrate the proper working relationships of the mating parts of an object and the function of each.
   2. To show a general idea of how the finished product should look.
   3. To assist in securing overall dimensions and center lines in assembly.
   4. To give the machinist data needed to design the smaller units of a larger object
   5. To provide illustrations which may be used for maintenance manuals or other purposes.

Practical Application:

Students will be able to readily identify all covered views and to discuss the purposes of each. Students will also select the proper parts from an array to fulfill the requirements of the assembly drawing.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-C5) dealing with the verification of drawing elements.

CNC-C4-HO
List the Purpose of Each Type of Drawing
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:
- a. Identify the purpose of orthographic (3 views) drawings;
- b. Identify the purpose of isometric drawing;
- c. Identify the purpose of exploded isometric drawing; and,
- d. Identify the purpose of assembly drawings.

Module Outline:

NB: The Self-Assessment for this module is greatly dependent on the engineering drawings presented. Therefore, the instructor must complete the questions for the Self-Assessment. The editors strongly recommend a minimum of twenty questions for this module.

- I. Identify the Purpose of Orthographic Views
  - A. Any orthographic drawing must have a minimum of two views in order to show an object completely.
  - B. The top view may be referred to as the plan view. The front or side views may be referred to as the elevations views.
- II. Identify Positions of Views (Top, Front, Side, and Auxiliary)
  - A. Top, is usually to the left and at the top of the print when viewing a single object, and represents the objects top if you were looking down at it.
  - B. Front is directly below the top view, and on the same center line as the top. The front does not necessarily mean the actual front of the object.
  - C. Side or sometimes referred as the right side is normally the right side of the front view and is on the same center lines as well as the same elevation.
- III. Visualize One or More Views from a Given View
  - A. In any given view the student can visualize more then one side of a object. The object can be shown in one of many positions.
- IV. Identify Isometric Views
  - A. Any object can be drawn from four different directions isometrically, but there is usually one view that best shows the object.
  - B. When using isometrics the student should be familiar with the isometric axes, and the term preferred north and alternate north.
  - C. In the isometric format, the lines of the object remain parallel and the object is drawn about the three isometric axes that are 120° degrees apart which is at 30° from the plane of the drawing.

D. Isometrics distort dimensions; therefore, you cannot draw isometrics to scale.

V. Identify Exploded Isometric Drawings

A. An *exploded drawing* is a picture of an assembly of several parts drawn isometrically to show the proper steps in assembling a unit.

VI. Identify Assembly Drawings

A. *Assembly drawings* are drawings in which the various parts of an object are shown in their relative positions in the completed unit.

B. Assembly drawings are also used:

1. To illustrate the proper working relationships of the mating parts of an object and the function of each.
2. To show a general idea of how the finished product should look.
3. To assist in securing overall dimensions and center lines in assembly.
4. To give the machinist data needed to design the smaller units of a larger object
5. To provide illustrations which may be used for maintenance manuals or other purposes.

Name____________________________ Date_______________

CNC-C4
List the Purpose of Each Type of Drawing
Self-Assessment

Circle the letter preceding the correct answer.

1. In a orthographic drawing, what are the minimum views used that could show an object completely?
   - A. 1
   - B. 2
   - C. 3
   - D. The minimum number of views depends on the number of faces the object has.
   - E. None of the above answers is correct.

2. In a orthographic drawing, what is the normal number of views used?
   - A. 1
   - B. 2
   - C. 3
   - D. Orthographic drawings have no "normal" number of views.
   - E. None of the above answers is correct.

3. In an isometric drawing, the object is drawn at what angle?
   - A. 45°
   - B. 30°
   - C. 90°
   - D. Isometric drawings are rendered perpendicular to the plane of view.
   - E. None of the above answers is correct.

4. Assembly drawings are used to:
   - A. To show a general idea of how the finished product should look.
   - B. To assist in securing overall dimensions and center lines in assembly.
   - C. To give the machinist data needed to design the smaller units of a larger object
   - D. All of the above are legitimate uses of assembly drawings.
   - E. None of the above answers is correct.

CNC-C4
List the Purpose of Each Type of Drawing
Self-Assessment Answer Key

1. B

2. C

3. B

4. D

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-C5

Subject: Advanced CNC and CAM **Time: 2 Hrs.**

Duty: Interpret Engineering Drawings and Control Documents
Task: Verify Drawing Elements

Objective(s):

Upon completion of this unit the student will be able to:

a. Recognize out-of-date blueprints;
b. Check for revisions; and,
c. Determine the scale of the view or section.

Instructional Materials:

MASTER Handout (CNC-C5-HO)
MASTER Self-Assessment
Set of obsolete blueprints
Set of current blueprints for comparison

References:

How to Read Shop Prints and Drawings, William E. Hardman, National Tooling & Machining Association, Latest Edition, "Introduction to Shop Prints"
Technical Drawing, Giesecke, Mitchell, Spencer, Hill, Dygdon, and Novak, MacMillan Publishing, Latest Edition, "Design and Working Drawings"
Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition, "Reading Drawings"

Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-C1	"Identify Basic Layout of Drawings"
CNC-C2	"Identify Basic Types of Drawings"
CNC-C3	"Review Blueprint Notes and Dimensions"
CNC-C4	"List the Purpose of Each Type of Drawing"

Introduction:

As with all other aspects of today's society, blueprints are constantly changing. New models replace old models on a daily basis; old models seem to be updated hourly. Due to this ever-raging storm of change, all machinists must be familiar with those signs which announce to them that their particular blueprints may not be the most current design. Failure to recognize obsolete blueprints can result in lost work, scrap, and lost profits to the industry.

Presentation Outline:

I. Recognize Out-of-Date Blueprints
    A. Check title block for date of completion (*Drawn By*)
    B. Check title block for date of certification (*Checked By*)
    C. Check title block for discontinuation (*Replaced By*)
    D. Check title block for what the new drawing replaces (*Replaces*)
II. Check for Revisions
    A. Revisions are usually listed in a separate block
    B. Revision (change) lists usually contain the following blocks:
        1. **Zone** (on large drawing sheets) shows the area of the revision, using an alphanumeric Cartesian plane
        2. **Revision** shows the exact location of the revision, usually by an alphabetic indicator
        3. **Description** gives a brief description of the change, such as a size change, a new part, or an angular cut difference
        4. **Date** indicates the date the revision was approved and became effective
        5. **Approved By** usually abbreviated, this block shows the person who approved the individual change
III. Determine the Scale of the View or Section
    A. Check the title block for the overall scale of the drawing
    B. Each detail view must be checked for scale
    C. Notes on scale
        1. **Full or 1:1**--the part is drawn to its actual size
        2. **Half** or **1/2:1**--the part is drawn to one-half its actual size
        3. Any other scale would be distinctly noted
IV. The Word *Noted* in Any Block Indicates That the Desired Information Can Be Found Written Somewhere on the Drawing, Usually Very Close to the Area to Which it Applies

Practical Application:

The student should be able to quickly recognize obsolete blueprints.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-C6) dealing with geometric dimensioning and tolerancing (GD&T).

CNC-C5-HO
Verify Drawing Elements
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Recognize out-of-date blueprints;
b. Check for revisions; and,
c. Determine the scale of the view or section.

Module Outline:

I. Recognize Out-of-Date Blueprints
    A. Check title block for date of completion (*Drawn By*)
    B. Check title block for date of certification (*Checked By*)
    C. Check title block for discontinuation (*Replaced By*)
    D. Check title block for what the new drawing replaces (*Replaces*)
II. Check for Revisions
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        4. **Date** indicates the date the revision was approved and became effective
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III. Determine the Scale of the View or Section
    A. Check the title block for the overall scale of the drawing
    B. Each detail view must be checked for scale
    C. Notes on scale
        1. **Full or 1:1**--the part is drawn to its actual size
        2. **Half or 1/2:1**--the part is drawn to one-half its actual size
        3. Any other scale would be distinctly noted
IV. The Word *Noted* in Any Block Indicates That the Desired Information Can Be Found Written Somewhere on the Drawing, Usually Very Close to the Area to Which it Applies

Name____________________________ Date_______________

CNC-C5
Verify Drawing Elements
Self-Assessment

Circle the letter preceding the correct answer.

1. The title block does *not* contain:
   - A. The name of the person who authorized the specific revision.
   - B. The identification number of the drawing it replaces.
   - C. The overall drawing scale.
   - D. All of the above can be found in the title block.
   - E. None of the above answers is correct.

2. Revision blocks:
   - A. Contain the exact physical location of the revision.
   - B. Identify the person who approved the revision.
   - C. Show the date of the revision.
   - D. All of the above information is in the revision block.
   - E. None of the above answers is correct.

3. The word ___ indicates that the information can be found in the body of the drawing.
   - A. Referral
   - B. Detail
   - C. Noted
   - D. Incorporated
   - E. None of the above answers is correct.

4. The scale notation ___ means that the drawing is drawn to the same size as the part which it represents.
   - A. 1/2:1
   - B. 1:1
   - C. Full
   - D. Answers A anc C are the same and both are correct.
   - E. Answers B and C are the same and both are correct.

5. The scale notation 1/2:1:
   - A. Indicates that the drawing is one-half the size of the part.
   - B. Is the same as the notation *half.*
   - C. Is not commonly found.
   - D. Both A and B.
   - E. Both B and C.

6. A ___ is that portion of the drawing that is represented by an alphanumeric Cartesian coordinate.
   A. Region
   B. Zone
   C. Dimension
   D. All of the above answers are applicable.
   E. None of the above answers is correct.

7. Both the *Drawn By* date and the *Replaced By* identification can be found in the:
   A. Title block
   B. Revision list
   C. Bill of materials
   D. All of the above answers are correct.
   E. None of the above answers is correct.

8. Which of the following is *not located* in the revision list?
   A. Effective date
   B. Zone
   C. Description
   D. All of the above answers are correct.
   E. None of the above answers is correct.

9. The revision list is also known as the:
   A. Change list.
   B. Additions & Deletions list.
   C. Control block.
   D. Verification block.
   E. None of the above answers is correct.

10. Using obsolete blueprints can result in:
   A. Lost work.
   B. Loss of materials.
   C. Lowered profits.
   D. All of the above answers are correct.
   E. None of the above answers is correct.

CNC-C5
Verify Drawing Elements
Self-Assessment Answer Key

1. A

2. D

3. C

4. E

5. D

6. B

7. A

8. D

9. A

10. D

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-C6

Subject: **Advanced CNC and CAM** **Time: 8 Hrs.**

Duty: **Interpret Engineering Drawings and Control Documents**
Task: Practice Geometric Dimensioning and Tolerancing (GD&T)

Objective(s):

Upon completion of this unit the student will be able to:

a. Identify the purpose of GD&T;
b. Identify symbols for controlling location (or true position) of part features;
c. Identify symbols for controlling form (or alignment) of part features;
d. Identify symbols for showing datums and basic dimensions on drawings; and,
e. Identify symbols for Maximum Material Size (MMS) and Regardless of Feature Size (RFS).

Instructional Materials:

MASTER Handout (CNC-C6-HO)
MASTER Self-Assessment
Blueprints with GD&T notations
Parts correspondent to the selected blueprints

References:

Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition, "Tolerances and Fits"
Introduction to Geometric Dimensioning and Tolerancing, Lowell W. Foster, National Tooling & Machining Association, Latest Edition
Machinery's Handbook, Industrial Press, Latest Edition

Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-C1	"Identify Basic Layout of Drawings"
CNC-C2	"Identify Basic Types of Drawings"
CNC-C3	"Review Blueprint Notes and Dimensions"
CNC-C4	"List the Purpose of Each Type of Drawing"
CNC-C5	"Verify Drawing Elements"

Introduction:

Geometric Dimensioning and Tolerancing is used whenever the location of the part is as critical or more critical than its actual size. GD&T actually ensures that parts from different manufacturers will mate properly or can be mutually substituted.

Presentation Outline:

I. Identify the Purpose of GD&T
In industry today, there are many companies competing for replacement parts to replace ones that have worn out. They are geared more towards, and can handle, part replacement better than the companies that made the original unit. Realizing this, manufacturers and the engineering community have used Geometric Dimensioning and Tolerancing to maintain replacement part unity. For example, a part for your car was originally made by Mammoth Motor Company; but when you go to a parts house, they supply you with a part from Acme Auto Parts.

II. Identify Symbols for Controlling Location (Or True Position) of Part Features
True position, Concentricity, and *Symmetry* are used to indicate location control. Many units have a particular bolt pattern; if you were to replace one of the two units with another unit made from a different manufacturer, it may not have the same bolt pattern and would not be compatible.

III. Identify Symbols for Controlling Form (Or Alignment) of Part Features
Perpendicularity (squareness) is one example of form that must be controlled during manufacturing. The following list of symbols indicate types of form control:

1. Straightness;
2. Flatness;
3. Angularity;
4. Parallelism;
5. Roundness;
6. Cylindricity
7. Profile of any line;
8. Profile of any surface; and,
9. Runout (circular or total).

IV. Identify Symbols for Showing Datums and Basic Dimensions on Drawings
Datums are reference points, lines, and planes taken to be exact for the purposes of calculation and measurement. They are placed in a rectangular frame and are identified by single or double letters. I, O, and Q are not used.

V. Identify Symbols for Maximum Material Condition (MMC) and Regardless of Feature Size (RFS)

A. (MMC) refers to the maximum amount of material remaining.

B. (RFS) refers to means that the form or position tolerance of a feature must be met no matter what the feature size is.

Practical Application:

Students will understand the uses and applications of GD&T and be able to recognize the symbols thereof.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-C7) dealing with the analysis of bills of materials.

CNC-C6-HO
Practice Geometric Dimensioning and Tolerancing (GD&T)
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Identify the purpose of GD&T;
b. Identify symbols for controlling location (or true position) of part features;
c. Identify symbols for controlling form (or alignment) of part features;
d. Identify symbols for showing datums and basic dimensions on drawings; and,
e. Identify symbols for Maximum Material Size (MMS) and Regardless of Feature Size (RFS).

Module Outline:

I. Identify the Purpose of GD&T
In industry today, there are many companies competing for replacement parts to replace ones that have worn out. They are geared more towards, and can handle, part replacement better than the companies that made the original unit. Realizing this, manufacturers and the engineering community have used Geometric Dimensioning and Tolerancing to maintain replacement part unity. For example, a part for your car was originally made by Mammoth Motor Company; but when you go to a parts house, they supply you with a part from Acme Auto Parts.

II. Identify Symbols for Controlling Location (Or True Position) of Part Features
True position, *Concentricity*, and *Symmetry* are used to indicate location control. Many units have a particular bolt pattern; if you were to replace one of the two units with another unit made from a different manufacturer, it may not have the same bolt pattern and would not be compatible.

III. Identify Symbols for Controlling Form (Or Alignment) of Part Features
Perpendicularity (squareness) is one example of form that must be controlled during manufacturing. The following list of symbols indicate types of form control:

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4. Parallelism;
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6. Cylindricity
7. Profile of any line;
8. Profile of any surface; and,

    9. Runout (circular or total).

IV. Identify Symbols for Showing Datums and Basic Dimensions on Drawings
Datums are reference points, lines, and planes taken to be exact for the purposes of calculation and measurement. They are placed in a rectangular frame and are identified by single or double letters. I, O, and Q are not used.

V. Identify Symbols for Maximum Material Condition (MMC) and Regardless of Feature Size (RFS)
  A. (MMC) refers to the maximum amount of material remaining.
  B. (RFS) refers to means that the form or position tolerance of a feature must be met no matter what the feature size is.

Name______________________________ Date_________________

CNC-C6
Practice Geometric Dimensioning and Tolerancing
Self-Assessment

Circle the letter preceding the correct answer.

1. True position means location could be more important than actual size. Why is this important?
   - A. Not all the parts of an assembly may be made of the same material.
   - B. Not all the parts of an assembly may be made in the same factory.
   - C. Not all the parts of an assembly may be made by the same manufacturer.
   - D. All of the above answers are correct.
   - E. None of the above answers is correct.

2. Geometric Dimensioning and Tolerancing was developed:
   - A. By replacement parts manufacturers.
   - B. To facilitate exchange ability of parts.
   - C. To be a simple subject, quickly learned.
   - D. All of the above answers are correct.
   - E. None of the above answers is correct.

3. MMC refers to the:
   - A. Maximum amount of material remaining.
   - B. Minimum amount of material remaining.
   - C. Maximum material condition.
   - D. Minimum material condition.
   - E. None of the above answers is correct.

4. RFS means that:
   - A. The part must function, regardless of its size.
   - B. The part's position tolerance is more important than its size.
   - C. The lathe must turn at a *R*eally *F*ast *S*pin.
   - D. All of the above answers are correct.
   - E. None of the above answers are correct.

5. A *datum* is a ___ taken to be exact for the purpose of calculations and measurements.
A. Reference point
B. Line
C. Plane
D. All of the above answers are correct.
E. None of the above answers is correct.

6. The symbol "//" indicates:
A. Perpendicularity.
B. Parallelism.
C. Concentricity.
D. There is no such symbol in GD&T.
E. None of the above answers is correct.

7. The symbol "◉" indicates:
A. Perpendicularity.
B. Parallelism.
C. Concentricity.
D. There is no such symbol in GD&T.
E. None of the above answers is correct.

8. $\boxed{.375}$ This box indicates that the number contained therein is:
A. A basic dimension.
B. An exact dimension.
C. A positional indicator.
D. Both A and C are correct.
E. Answers A and B are the same and are correct.

9. ___ is an orientation tolerance.
A. Perpendicularity.
B. Parallelism.
C. Angularity.
D. All of the above are orientation tolerances.
E. None of the above answers is correct.

10. Which of the following is *not* a form tolerance?
A. Circularity
B. Concentricity
C. Cylindricity
D. All of the above are form tolerances.
E. None of the above answers is correct.

CNC-C6
Practice Geometric Dimensioning and Tolerancing
Self-Assessment Answer Key

1. C
2. B
3. C
4. B
5. D
6. B
7. C
8. E
9. D
10. B

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-C7

Subject: **Advanced CNC and CAM** **Time: 2 Hrs.**

Duty: **Interpret Engineering Drawings and Control Documents**
Task: Analyze Bill of Materials (BOM)

Objective(s):

Upon completion of this unit the student will be able to:

a. Know which components are found on BOM;
b. Determine which materials are needed to produce the part;
c. Determine the quantities necessary to produce the part;
d. Submit a completed stock request form as required; and,
e. Submit a completed tool request form as needed.

Instructional Materials:

MASTER Handout (CNC-C7-HO)
MASTER Self-Assessment
Copies of blueprints with bills of materials

References:

Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition, "Reading Drawings"
Blueprint Reading for Manufacturing, Edward G. Hoffman and Paul K. Wallach, Delmar Publishers, Inc., Latest Edition, "Detail and Assembly Prints"

Student Preparation:

Introduction:

Before anything can be built, its builder must know what to build it from. While the body of the drawing shows the positions and sizes of parts and all the necessary cuts and corners, the bill of materials tells which materials the machinist needs to complete the work at hand. This bill of materials may include commercially available parts, or may specify the necessary stock sizes.

Presentation Outline:

I. Discuss Components Found on BOM
    A. Item or Part Number, relative to the body of the drawing
    B. Description of Item
    C. Specification
    D. Material Needed
    E. Number Required
II. Determine Materials Needed to Produce the Part
III. Determine Quantities Necessary to Produce the Part
IV. Submit Completed Stock Request Form as Required
    This topic is company-specific and must be designed at such level. The instructor is encouraged to be extremely general in comments, covering only those areas of stock requests that are universal in application.
V. Submit Completed Tool Request Form as Needed
    Here, too, the instructor must generalize and emphasize that s/he is generalizing.

Practical Application:

Students will be able to recognize and analyze Bills of Materials and to complete the required stock request forms from the Bill of Materials.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-C8) dealing with the relationship between engineering drawings and planning.

CNC-C7-HO
Analyze Bill of Materials (BOM)
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Know which components are found on BOM;
b. Determine which materials are needed to produce the part;
c. Determine the quantities necessary to produce the part;
d. Submit a completed stock request form as required; and,
e. Submit a completed tool request form as needed.

Module Outline:

I. Discuss Components Found on BOM
    A. Item or Part Number, relative to the body of the drawing
    B. Description of Item
    C. Specification
    D. Material Needed
    E. Number Required
II. Determine Materials Needed to Produce the Part
III. Determine Quantities Necessary to Produce the Part
IV. Submit Completed Stock Request Form as Required
    This topic is company-specific and must be designed at such level. The instructor is encouraged to be extremely general in comments, covering only those areas of stock requests that are universal in application.
V. Submit Completed Tool Request Form as Needed
    Here, too, the instructor must generalize and emphasize that s/he is generalizing.

Name_______________________________ Date_________________

CNC-C7
Analyze Bill of Materials (BOM)
Self-Assessment

Using the sample BOM, answer the questions below.

32	Key	1/4 x 1/4 x 1	Steel	3
24	Set Screw	3/8x1/4 - 16 NF	COMM	1
23	Ball Knob	P/N 15032	COMM	1
21	Handle	½ DIA	Naval Brass	1
Part Number	Description	Specification	Material	Number

1. Part #21 is made of _____.

2. Does the machinist have to make the ball knob? ________________

3. How many keys does the part require? ___________________________

4. What are the dimensions of the keys? ___________________________

5. What are the specifications for the set screw? ___________________

6. Which part(s) is commercially available? ______________________

7. How many handles are required? ________________________________

8. What size is the ball knob? _____________________________________

9. What is Part #24 in the drawing? _________________________________

10. Does the BOM imply that the grade of steel for the keys is critical?_____

CNC-C7
Analyze Bill of Materials (BOM)
Self-Assessment Answer Key

1. Naval Brass
2. No, the part is marked as commercially available.
3. Three (3)
4. 1/4 x 1/4 x 1
5. 3/8 x 1/4 - NF
6. Set Screw and Ball Knob
7. One (1)
8. The size of the ball knob is not specified in the BOM because the part is commercially available. Any answer indicating this, including "Unknown" or "Not Specified" is acceptable.
9. Set Screw
10. No, there is no specification for the type or strength of the steel.

ADVANCEC CNC and CAM SERIES

MASTER Technical Module No. CNC-C8

Subject: **Advanced CNC and CAM** **Time: 4 Hrs.**

Duty: **Interpret Engineering Drawings and Control Documents**
Task: Describe the Relationship of Engineering Drawings to Planning

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Objective(s):

Upon completion of this unit the student will be able to:
a. Discuss production schedules;
b. Understand Material Resource Planning (MRP);
c. Recognize and utilize inventory control records; and,
d. Recognize and follow specific shop floor routing documents.

Instructional Materials:

MASTER Handout (CNC-C8-HO)
MASTER Self-Assessment
All instructional materials should be specific to a particular shop, if possible. General documents may be used in other cases.
Shop-floor routing documents
Receipt of Goods documents
Waste Management documents
Return of Goods documents
Tool Room accounts and documents
Machine Time documents

References:

Student Preparation:

Introduction:

In a perfect world, all shops would get exactly the materials they needed at the exact moment that they needed them. This is not a perfect world. Profit drives scheduling, and well-organized, well-run shops are more profitable than those that are not so well run.

At the heart of organization is planning. Planning is driven by the customer, who places an order and agrees to a delivery date. Happy customers are the result of excellence not only in product performance, but also in service. Critical to excellence in service is timely delivery of the promised product which goes back to (you guessed it) planning.

Presentation Outline:

- I. Discuss Production Schedule
  - A. Internal Factors
    - 1. Available personnel and equipment
    - 2. Priority
    - 3. Setup time
    - 4. Parts per man-hour (quotas)
    - 5. Warehouse to shop floor time for stock
    - 6. Shop floor to shipping department time for parts
  - B. External factors
    - 1. Customer deadlines
    - 2. Material delivery schedules
- II. Discuss Material Resource Planning (MRP)
  - A. Volume of production
  - B. Required stock
    - 1. Types of stock needed
    - 2. Amounts of stock needed
  - C. Waste management
  - D. Mechanical management
    - 1. Tool wear and replacement
    - 2. Machine down-time
- III. Discuss Inventory Control Records
  - A. Receipt of goods documents
  - B. Waste management documents
  - C. Return of goods documents
  - D. Tool room accounts and documents
  - E. Machine time documents
- IV. Discuss Shop Floor Routing Documents

  These documents vary in detail from shop to shop. The instructors should use documents from their own shops to explain both the theory and practice of routing documents.

Practical Application:

All students should be able to understand their roles in the production schedule and the importance of the documentation of the stock, parts, and tools to production and profitability.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-C9) dealing with understanding quality systems and the machinist's role in quality.

CNC-C8-HO
Describe the Relationship of Engineering Drawings to Planning
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Discuss production schedules;
b. Understand Material Resource Planning (MRP);
c. Recognize and utilize inventory control records; and,
d. Recognize and follow specific shop floor routing documents.

Module Outline:

I. Discuss Production Schedule
  A. Internal Factors
    1. Available personnel and equipment
    2. Priority
    3. Setup time
    4. Parts per man-hour (quotas)
    5. Warehouse to shop floor time for stock
    6. Shop floor to shipping department time for parts
  B. External factors
    1. Customer deadlines
    2. Material delivery schedules
II. Discuss Material Resource Planning (MRP)
  A. Volume of production
  B. Required stock
    1. Types of stock needed
    2. Amounts of stock needed
  C. Waste management
  D. Mechanical management
    1. Tool wear and replacement
    2. Machine down-time
III. Discuss Inventory Control Records
  A. Receipt of goods documents
  B. Waste management documents
  C. Return of goods documents
  D. Tool room accounts and documents
  E. Machine time documents
IV. Discuss Shop Floor Routing Documents

These documents vary in detail from shop to shop. The instructors should use documents from their own shops to explain both the theory and practice of routing documents.

Name______________________________ Date________________

CNC-C8
Describe the Relationship of Engineering Drawings to Planning
Self-Assessment

Circle the letter preceding the correct answer.

1. When determining the amount of materials needed for production, the technician should consult:
   A. The original order.
   B. The blueprint BOM.
   C. The inventory report.
   D. All of the above should be consulted.
   E. None of the above answers is correct.

2. A part run requires five hundred pieces. If five pieces can be made from one three-foot piece of 1" CRS, how many such pieces does the technician need to complete the run? Assume 1% waste.
   A. 99
   B. 100
   C. 101
   D. This is a problem for the engineers to solve before it gets to me.
   E. None of the above answers is correct.

3. One technician can make one hundred good widgets in four hours. What is the technician's production in parts per man-hour? Assume 4% waste.
   A. 20
   B. 25
   C. 26
   D. 12.5
   E. None of the above answers is correct.

4. The technician is receiving fifty pieces of stock for a production run. What should the technician do *before* signing the receipt of goods?
   A. Verify the type of material listed.
   B. Verify the amount of material listed.
   C. Nothing
   D. Both A and B
   E. None of the above answers is correct.

5. If a particular tool wears out after 300 hours of contact, and five parts can be cut with it in one hour, how many parts will the tool cut before it needs to be replaced?
   A. 60
   B. 300
   C. 1500
   D. None of the above answers is correct.

6. If six technicians make one hundred twenty parts in thirty minutes, what is their production per man-hour?
   A. 20
   B. 40
   C. 120
   D. 240
   E. None of the above answers is correct.

7. A part is produced at a rate of twelve per man hour. An emergency order has come in for 60 such parts to be picked up in two hours. How many technicians are needed to produce the part? Assume that all other factors of production consume one hour of the allotted time.
   A. 3
   B. 4
   C. 5
   D. 6
   E. None of the above answers is correct.

Questions 8, 9, and 10 all deal with routing of parts and materials through the shop. Instructors should compose these questions from their available documents.

CNC-C8
Describe the Relationship of Engineering Drawings to Planning
Self-Assessment Answer Key

1. B

2. C

3. B

4. D

5. C

6. B

7. C

8.

9.

10.

CNC-C9

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-C9

Subject: **Advanced CNC and CAM** **Time: 32 Hrs.**

Duty: **Interpret Engineering Drawings and Control Documents**
Task: Understand and Use Quality Systems

Objective(s):

Upon completion of this unit the student will be able to:

a. Understand and apply quality principles, including continuous improvement; and,
b. Document paper trails for part revisions.

Instructional Materials:

MASTER Handout (CNC-C9-HO)

References:

Student Preparation:

Introduction:

The ultimate goal of all technicians is to fabricate perfect parts and make absolute repairs. Unfortunately, we just can't get there from here. However, with the consistent application of quality controls *at every level*, we can get close.

Presentation Outline:

I. Understand and Apply Quality Principles, Including Continuous Improvement
   A. Tolerances as basic quality control
   B. The machinist as the first line of excellence
   C. Specific systems
   These systems are diverse. You, as the instructor, must tailor this portion of the lecture to the system used in your circumstances.
   D. The inspector as guarantor
   E. The consumer: the ultimate judge of top quality

II. ISO 9000
    A. Purpose
    B. What is ISO 9000?
    C. How does is work?
    D. Where do the standards come from?
    E. Who uses this stuff, anyway?
III. Document Paper Trails for Part Revisions

Practical Application:

Due to the large number of quality assurance systems, the instructor must tailor the Self-Assessment to his own company.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-C10) discussing the use of standards and the verification of requirements.

CNC-C9-HO
Understand and Use Quality Systems
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Understand and apply quality principles, including continuous improvement; and,

b. Document paper trails for part revisions.

Module Outline:

I. Understand and Apply Quality Principles, Including Continuous Improvement
  A. Tolerances as basic quality control
  B. The machinist as the first line of excellence
  C. Specific systems
     These systems are diverse. You, as the instructor, must tailor this portion of the lecture to the system used in your circumstances.
  D. The inspector as guarantor
  E. The consumer: the ultimate judge of top quality

II. ISO 9000
  A. Purpose
  B. What is ISO 9000?
  C. How does is work?
  D. Where do the standards come from?
  E. Who uses this stuff, anyway?

III. Document Paper Trails for Part Revisions

CNC-C10

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-C10

Subject: **Advanced CNC and CAM** **Time: 4 Hrs.**

Duty: **Interpret Engineering Drawings and Control Documents**
Task: Verify Standard Requirements

Objective(s):

Upon completion of this unit the student will be able to:
a. Discuss the purpose of standards; and,
b. Discuss source locations for standards.

Instructional Materials:

MASTER Handout (CNC-C10-HO)
The instructor must use corporate resources, such as obsolete plans and masters
Steel rule (any)
Representative gage blocks (any)
Sample of any metal showing a control stamp

References:

Machinery's Handbook, Industrial Press, Latest Edition

Student Preparation:

Students shall have completed all CNC C-series modules.

Introduction:

Long before Henry Ford introduced modern manufacturing with his assembly lines, even before Samuel Colt mass-produced interchangeable cylinders for his pistols, the principles of reproducibility were introduced in France. In the waning days of the Eighteenth Century, French women bombarded the cloth industry with demands for complex, repeating patterns for their dresses. Single colors and unique designs were no longer acceptable to the French nobility. From this demand, the Jacquard loom arose. This revolutionary loom gave rise, ultimately, to the computer; but that is a different story. What is important here is that Monsieur Jacquard established a *definite, repeatable standard* for a mass-production industry. And, while he was not the first to try to do so, he was the first to succeed on such a large scale. The Jacquard loom required that wooden cards be cut with identical patterns of holes which controlled the operation of the loom; this lead to the use of brass masters against which all wooden cards were measured. The practice of having a physical unit standard, against which all others were measured, was in use until late in the Twentieth Century, when atomic emissions made platinum-iridium bars obsolete. In a world demanding reproducible, interchangeable parts, even for patterns in cloth, standards are utterly indispensable.

Presentation Outline:

- I. Discuss the Purpose of Standards
  - A. What are standards, anyway?
  - B. Why have standards at all?
  - C. How does a technician use today's standards?
  - D. The technician's role in quality as it relates to standards.
- II. Discuss Source Locations for Standards
  - A. Shop/company sources—*Machinery's Handbook*, especially
  - B. Industry sources
  - C. Governmental sources
- III. Oral Shorthand—Nominal Sizes vs. Actual Sizes

Practical Application:

The students will be able to look up and interpret standards of measurement, tolerances, and masters.

Evaluation and/or Verification:

This module has no Self-Assessment. The evaluation and verification of the student's understanding of the principles and uses of standards are on-going throughout the *entire course* of study. The instructor may, however, decide to have the students study the several charts found in *Machinery's Handbook* to increase their understanding of standard sizes and tolerances.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-D1) dealing with identifying and selecting materials with desired properties.

CNC-C10-HO
Verify Standard Requirements
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:
- a. Discuss the purpose of standards; and,
- b. Discuss source locations for standards.

Module Outline:

- I. Discuss the Purpose of Standards
  - A. What are standards, anyway?
  - B. Why have standards at all?
  - C. How does a technician use today's standards?
  - D. The technician's role in quality as it relates to standards.
- II. Discuss Source Locations for Standards
  - A. Shop/company sources—*Machinery's Handbook*, especially
  - B. Industry sources
  - C. Governmental sources
- III. Oral Shorthand—Nominal Sizes vs. Actual Sizes

CNC MACHINIST .... **programs, edits, sets up, and operates CNC lathes, mills and grinders to perform machining operations necessary to produce workpieces to referenced engineering standards.**

Duties		Tasks												
A	Practice Safety	A-1 Follow safety manuals and all safety regulations/requirements	A-2 Use protective equipment	A-3 Follow safe operating procedures for hand and machine tools	A-4 Maintain a clean and safe work environment	A-5 MSDS/control chemical hazards								
B	Apply Mathematical Concepts	B-1 Perform basic arithmetic functions	B-2 Convert fractions/decimals	B-3 Convert Metric/English measurements	B-4 Perform basic algebraic operations	B-5 Use practical geometry	B-6 Understand basic trigonometry	B-7 Calculate speeds and feeds for machining	B-8 Use coordinate systems					
C	Interpret Engineering Drawings and Control Documents	C-1 Identify basic layout of drawings	C-2 Identify basic types of drawings	C-3 Review blueprint notes and dimensions	C-4 List the purpose of each type of drawing	C-5 Verify drawing elements	C-6 Practice Geometric Dimensioning and Tolerancing (GD&T)	C-7 Analyze bill of materials (BOM)	C-8 Describe the relationship of engineering drawings to planning	C-9 Understand and use quality systems	C-10 Verify standard requirements			
D	Recognize Different Manufacturing Materials and Processes	D-1 Identify materials with desired properties	D-2 Identify materials and processes to produce a part	D-3 Describe the heat treating process	D-4 Test metal samples for hardness	D-5 Understand welding operations								
E	Measure/Inspect	E-1 Understand metrology terms	E-2 Select measurement tools	E-3 Measure with hand held instruments	E-4 Eliminate measurement variables	E-5 Measure/inspect using surface plate and accessories	E-6 Inspect using stationary equipment							
F	Perform Conventional Machining	F-1 Prepare and plan for machining operations	F-2 Use hand tools	F-3 Operate power saws	F-4 Operate drill presses	F-5 Operate vertical milling machines	F-6 Operate horizontal milling machines	F-7 Operate metal cutting lathes	F-8 Operate grinding/abrasive machines					
G	Perform Advanced Machining	G-1 Understand CNC basics	G-2 Program CNC machines	G-3 Operate CNC machining centers (mills)	G-4 Operate CNC turning centers (lathes)									
H	Use Verification and Communication Systems	H-1 Use personal computer	H-2 Use various operating systems	H-3 Use computer communications systems	H-4 Use verification systems	H-5 Use the Internet								
I	Program Using CAM System	I-1 Understand CAD/CAM programs	I-2 Manipulate CAD functions	I-3 Process simple tool-path data	I-4 Create advanced surface models	I-5 Process complex tool-path functions								

CNC-D1

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-D1

Subject: **Advanced CNC and CAM** **Time: 2 Hrs.**

Duty: **Recognize Different Manufacturing Materials and Processes**
Task: Identify Materials With Desired Properties

Objective(s):

Upon completion of this unit the student will be able to:

a. Discuss classification system for metals; and,

b. Describe general characteristics for carbon steels, tool steels, stainless steels, structural steels, cast irons, aluminum, and other commonly used metals.

Instructional Materials:

MASTER Handout (CNC-D1-HO1)

The following tables are included in this module for reference or reproduction as needed.

Table 1.1 "Effects of Alloying Elements on Steel" (CNC-D1-HO2)

Table 1.2 "SAE-ANSI Numerical Designation of Alloy Steels" (CNC-D1-HO3)

MASTER Self-Assessment

References:

Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition, "Selection and Identification of Steels" and "Selection and Identification of Non-Ferrous Metals"

NTMA Modules:

MA-II-46	"Physical Metallurgy"
MA-II-77	"Cast Irons"
MA-II-48	"Property of Metals"
MA-II-79	"Powder Metallurgy"
MA-II-50	"Iron Carbon Constitutional Diagram"
MA-II-57	"Steel Classification & Basic Tests for Identifying the Content of an Unknown Metal"
MA-II-59	"Plain Carbon Steel"
MA-II-67	"Alloy Steels and Stainless Steels"
MA-II-69	"Aluminum & Aluminum Alloys"
MA-II-71	"Magnesium & Magnesium Alloys"

MA-II-73 "Copper & Copper Alloys"
MA-II-75 "Other Nonferrous Metals & Cast Alloys"
Machinery's Handbook, Industrial Press, Latest Edition

Student Preparation:

None

Introduction:

It has become increasingly important for the machinist to understand the properties of metals during the last few years. With more and more emphasis on weight reduction and increased strength in products such as automobiles and aircraft, the machinist will be expected to work with many different types of carbon and alloy steels. So it is imperative that the machinist understand the properties and identification system for metals commonly found in the machine shop.

Presentation Outline:

- I. Discuss the Physical Properties of Metal
  - A. Brittleness - the property of a metal which permits no permanent distortion before breaking
  - B. Ductility - the ability of the metal to be permanently deformed without breaking
  - C. Elasticity - the ability of a metal to return to its original shape after any force acting upon it has been removed
  - D. Hardness - the resistance to forcible penetration
  - E. Malleability - the property of a metal which permits it to be hammered or rolled into other sizes and shapes
  - F. Tensile strength - the maximum amount of pull that a material will withstand before breaking
  - G. Toughness - the property of a metal to withstand shock or impact
- II. Discuss the Classification System for Steel
  - A. Carbon steels
    - 1. Low carbon steel - contains from 0.02 to 0.20 percent of carbon
    - 2. Medium carbon steel - contains from 0.30 to 0.60 percent of carbon
    - 3. High carbon steel (tool steel) - contains over 0.60 percent of carbon
  - B. Alloy steels - alloying elements allow steels to possess special characteristics
    Discuss Table 1.1 "Effects of Alloying Elements on Steel"
    Discuss Table 1.2 "SAE-ANSI Numerical Designation of Alloy Steels"
- III. Describe General Characteristics For:

A. Carbon Steels
B. Tool Steels
C. Stainless Steels
D. Structural Steels
E. Cast Irons
F. Non-Ferrous Metals
    1. Aluminum and Its Alloys
    2. Copper and Its Alloys
    3. Nickel Alloys
    4. Precious Metals
    5. Others

Practical Application:

Students will be able to select metals based on their properties through understanding their physical characteristics and the standard coding system.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions

Next Lesson Assignment:

MASTER Technical Module (CNC-D2) dealing with the identification of materials and processes used to produce a part.

CNC-D1-HO1
Identify Materials with Desired Properties
Attachment 1: MASTER Handout No. 1

Objective(s):

Upon completion of this unit the student will be able to:

a. Discuss classification system for metals; and,
b. Describe general characteristics for carbon steels, tool steels, stainless steels, structural steels, cast irons, aluminum, and other commonly used metals.

Module Outline:

I. Discuss the Physical Properties of Metal
    A. Brittleness - the property of a metal which permits no permanent distortion before breaking
    B. Ductility - the ability of the metal to be permanently deformed without breaking
    C. Elasticity - the ability of a metal to return to its original shape after any force acting upon it has been removed
    D. Hardness - the resistance to forcible penetration
    E. Malleability - the property of a metal which permits it to be hammered or rolled into other sizes and shapes
    F. Tensile strength - the maximum amount of pull that a material will withstand before breaking
    G. Toughness - the property of a metal to withstand shock or impact
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    A. Carbon steels
        1. Low carbon steel - contains from 0.02 to 0.20 percent of carbon
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        3. High carbon steel (tool steel) - contains over 0.60 percent of carbon
    B. Alloy steels - alloying elements allow steels to possess special characteristics
        Discuss Table 1.1 "Effects of Alloying Elements on Steel"
        Discuss Table 1.2 "SAE-ANSI Numerical Designation of Alloy Steels"
III. Describe General Characteristics For:
    A. Carbon Steels
    B. Tool Steels
    C. Stainless Steels
    D. Structural Steels
    E. Cast Irons

F. Non-Ferrous Metals
   1. Aluminum and Its Alloys
   2. Copper and Its Alloys
   3. Nickel Alloys
   4. Precious Metals
   5. Others

CNC-D1-HO2
Identify Materials With Desired Properties
Attachment 2: MASTER Handout No. 2

TABLES FOR CNC-D1 — PROPERTIES OF METALS
TABLE 1.1

THE EFFECT OF ALLOYING ELEMENTS ON STEEL

EFFECT	ELEMENT											
	Carbon	Chromium	Cobalt	Lead	Manganese	Molybdenum	Nickel	Phosphorus	Silicon	Sulfur	Tungsten	Vanadium
Increases tensile strength	X	X			X	X	X					
Increases hardness	X	X										
Increases wear resistance	X	X			X		X				X	
Increases hardenability	X	X			X	X	X					X
Increases ductility					X							
Increases elastic limit		X				X						
Increases rust resistance		X					X					
Increases abrasion resistance		X			X							
Increases toughness		X				X	X					X
Increases shock resistance		X					X					X
Increases fatigue resistance												X
Decreases ductility	X	X										
Decreases toughness			X									
Raises critical temperature		X	X								X	
Lowers critical temperature					X		X					
Causes hot shortness										X		
Causes cold shortness								X				
Imparts red hardness			X			X					X	
Imparts fine grain structure					X							X
Reduces deformation					X		X					
Acts as deoxidizer					X				X			
Acts as desulphurizer					X							
Imparts oil hardening properties		X			X	X	X					
Imparts air hardening properties					X	X						
Eliminates blow holes								X				
Creates soundness in casting									X			
Facilitates rolling and forging					X				X			
Improves machinability				X						X		

CNC-D1-HO3
Identify Materials With Desired Properties
Attachment 3: MASTER Handout No. 3

TABLE 1.2

SAE-AISI NUMERICAL DESIGNATION OF ALLOY STEELS *(X Represents Percent of Carbon in Hundredths)*	
Carbon Steels	
Plain carbon	10xx
Free-cutting, resulfurized	11xx
Manganese Steels	13xx
Nickel Steels	
.50% nickel	20xx
1.50% nickel	21xx
3.50% nickel	23xx
5.00% nickel	25xx
Nickel-Chromium Steels	
1.25% nickel, .65% chromium	31xx
1.75% nickel, 1.00% chromium	32xx
3.50% nickel, 1.57% chromium	33xx
3.00% nickel, .80% chromium	34xx
Corrosion and heat-resisting steels	303xx
Molybdenum Steels	
Chromium	41xx
Chromium-nickel	43xx
Nickel	46xx and 48xx
Chromium Steels	
Low-chromium	50xx
Medium-chromium	511xx
High-chromium	521xx
Chromium-Vanadium Steels	6xxx
Tungsten Steels	7xxx and 7xxxx
Triple-Alloy Steels	8xxx
Silicon-Manganese Steels	9xxx
Leaded steels	11Lxx (example)

Name______________________________ Date________________

CNC-D1
Identify Materials With Desired Properties
Self-Assessment

Circle the letter preceding the correct answer.

1. Using the SAE system, 1008 indicates:
   A. Plain carbon steel, 8% carbon.
   B. Plain carbon steel, 0.8% carbon
   C. Plain carbon steel, 0.08% carbon.
   D. Low-chromium steel, 0.08% carbon.
   E. None of the above answers is correct.

2. In the SAE system, triple-alloy steels are designated by the numeral:
   A. 6
   B. 7
   C. 8
   D. 9
   E. None of the above answers is correct.

3. The AISI system uses ___ to indicate the process used to manufacture the steel.
   A. Numerical prefixes
   B. Numerical suffixes
   C. Capital-letter prefixes
   D. Capital-letter suffixes
   E. None of the above answers is correct.

4. Which of the following does *not* increase the tensile strength of steel?
   A. Carbon
   B. Molybdenum
   C. Nickel
   D. All of the above elements increase the tensile strength of steel.
   E. None of the above answers is correct.

5. Which of the following elements decreases the *toughness* of steel?
   A. Cobalt
   B. Phosphorus
   C. Vanadium
   D. All of the above elements increase the toughness of steel.
   E. None of the above answers is correct.

6. Which of the following elements imparts *fine grain structure* to steel?
   A. Chromium
   B. Manganese
   C. Silicon
   D. Tungsten
   E. None of the above answers is correct.

7. The AISI prefix *B* designates that the steel is:
   A. Acid Bessemer carbon steel.
   B. Basic open hearth carbon steel.
   C. Acid open hearth carbon steel.
   D. Brass.
   E. None of the above answers is correct.

8. ___ steels have their own alphabetic classification system.
   A. Stainless
   B. Low-carbon
   C. Tool
   D. Austenitic
   E. None of the above answers is correct.

9. ___ stainless steel cannot be hardened by quenching.
   A. Austenitic
   B. Ferritic
   C. Martensitic
   D. All of the above stainless steels can be hardened by quenching.
   E. None of the above answers is correct.

10. Which of the following metals is magnetic?
   A. Phosphorus
   B. Silicon
   C. Sulfur
   D. All of the above metals are magnetic.
   E. None of the above answers is correct.

CNC-D1
Identify Materials With Desired Properties
Self-Assessment Answer Key

1. C
2. C
3. C
4. D
5. A
6. B
7. A
8. C
9. A
10. E

ADVANCED CNC and CAM SERIES
MASTER Technical Module No. CNC-D2

Subject: **Advanced CNC and CAM** **Time: 6 Hrs.**

Duty: **Recognize Different Manufacturing Materials and Processes**
Task: Identify Materials and Processes to Produce a Part

Objective(s):

Upon completion of this unit the student will be able to:

a. Briefly describe and list the advantages and disadvantages for each of the following: casting processes, hot working processes, and cold working processes;
b. Discuss service requirements (strength, hardness, etc.);
c. Discuss fastening processes (fasteners, welding, bonding, etc.); and,
d. Discuss corrosion resistance methods.

Instructional Materials:

MASTER Handout (CNC-D2-HO)
MASTER Self Assessment
Several samples of parts treated to resist corrosion by different methods
Several fasteners and samples of different bonding agents
Samples of metals showing exemplary welds
Samples of parts made by each process covered by the instructor

References:

Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition, Section on "Materials"
Machinery's Handbook, Industrial Press, Latest Edition

Student Preparation:

Students should have previously completed the following Technical Module:
CNC-D1 "Identify Materials with Desired Properties"

Introduction:

As in all other crafts, the materials of machining determine the properties of the part. While two pieces may appear the same to the naked eye, different metals have different strengths; and the two pieces may differ markedly in their performance.

Therefore, the machinist must be capable of identifying not only the material itself, but also its working properties.

Presentation Outline:

- I. Describe Casting Processes
  - A. Discuss the following casting processes: sand, evaporative, shell molding, permanent mold, centrifugal, investment, and die casting
  - B. Discuss pattern and mold design factors for each of the above casting processes
  - C. List the advantages and disadvantages of the casting processes
- II. Describe Hot Working Processes
  - A. Discuss the following hot working processes: rolling, strand casting, forging, drawing, extrusion, spinning, and roll forming
  - B. List the advantages and disadvantages of the hot working processes
- III. Describe Cold Working Processes
  - A. Discuss the following cold working processes: rolling, blanking, pressing, drawing, extruding, wire and bar drawing, bending, shearing, and roll forming
  - B. List the advantages and disadvantages of the cold working process
- IV. Evaluate Alternative Manufacturing Processes
  - A. Discuss the powder metallurgy process (PM)
  - B. Discuss the following nontraditional machining processes: EDM, laser machining, ultrasonic machining, hydrojet machining, electron beam machining, and plasma beam machining

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Practical Application:

Students will be able to recognize fasteners forms, casting processes, and novel machining methods and to readily identify the uses and advantages of each.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-D3) dealing with the heat treating process

CNC-D2-HO
Identify Materials and Processes to Produce a Part
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:

- a. Briefly describe and list the advantages and disadvantages for each of the following: casting processes, hot working processes, and cold working processes;
- b. Discuss service requirements (strength, hardness, etc.);
- c. Discuss fastening processes (fasteners, welding, bonding, etc.); and,
- d. Discuss corrosion resistance methods.

Module Outline:

- I. Describe Casting Processes
    - A. Discuss the following casting processes: sand, evaporative, shell molding, permanent mold, centrifugal, investment, and die casting
    - B. Discuss pattern and mold design factors for each of the above casting processes
    - C. List the advantages and disadvantages of the casting processes
- II. Describe Hot Working Processes
    - A. Discuss the following hot working processes: rolling, strand casting, forging, drawing, extrusion, spinning, and roll forming
    - B. List the advantages and disadvantages of the hot working processes
- III. Describe Cold Working Processes
    - A. Discuss the following cold working processes: rolling, blanking, pressing, drawing, extruding, wire and bar drawing, bending, shearing, and roll forming
    - B. List the advantages and disadvantages of the cold working process
- IV. Evaluate Alternative Manufacturing Processes
    - A. Discuss the powder metallurgy process (PM)
    - B. Discuss the following nontraditional machining processes: EDM, laser machining, ultrasonic machining, hydrojet machining, electron beam machining, and plasma beam machining

Name____________________________ Date________________

CNC-D2
Identify Materials and Processes to Produce a Part
Self-Assessment

Circle the letter preceding the correct answer.

1. In ___ casting, the mold is composed of sand and resin.
   A. Green-sand
   B. Shell
   C. V-process
   D. Squeeze
   E. None of the above answers is correct.

2. Which of the following is *not* a method of injecting material into a mold?
   A. Gravitic flow
   B. Pressure
   C. Centrifugal force
   D. All of the above are methods of injecting material into a mold.
   E. None of the above answers is correct.

3. What is the *skin effect?*
   A. The vacuoles created when the surface of a casting cools faster than its interior
   B. The thin, weak, exterior layer on castings caused by improper mixing of alloys
   C. The layers of metal formed in die casting
   D. Abrasions caused by excessive polishing of the casting
   E. Goose bumps

4. Die castings should be designed with ___ to relieve cooling stresses.
   A. Cores of simple shapes
   B. Heavy sections
   C. Small cores
   D. Uniform wall thicknesses
   E. None of the above answers is correct.

5. Which of the following is a major problem of the hot extrusion process?
   A. Cost of glass-powder lubricants
   B. Graphite lubricants contaminating the billet
   C. Construction of the equipment
   D. Scarcity of metals that can be successfully extruded
   E. None of the above answers is correct.

6. Extrusion generates ___ force, but not ___ force.
   - A. Tensile. . .compressive
   - B. Tensile. . .shear
   - C. Compressive. . .shear
   - D. Compressive. . .tensile
   - E. None of the above answers is correct.

7. Plasma cutters can generate heat in excess of:
   - A. 20,000°F.
   - B. 30,000°F.
   - C. 40,000°F.
   - D. 80,000°F.
   - E. 120,000°F.

8. Which of the following is *not* an advantage of EDM?
   - A. Localized heat treating
   - B. Extremely fine detail is possible.
   - C. Can be used on very hard metals.
   - D. All of the above answers are valid.
   - E. None of the above answers is correct.

9. Which of the following processes would be most advantageous for internal deburring operations?
   - A. ECDB
   - B. Hydrojet machining
   - C. Plasma machining
   - D. Laser machining
   - E. None of the above answers is correct.

10. What is meant by *ELG?*
    - A. Extremely Large Gauge
    - B. Electrolytic Grinding
    - C. Emerald Laser Grinding
    - D. Electron-Lathe Guide
    - E. None of the above answers is correct.

CNC-D2
Identify Materials and Processes to Produce a Part
Self-Assessment Answer Key

1. B

2. D

3. C

4. D

5. C

6. D

7. C

8. A

9. A

10. B

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-D3

Subject: **Advanced CNC and CAM** **Time: 4 Hrs.**

Duty: **Recognize Different Manufacturing Materials and Processes**
Task: Describe the Heat Treating Process

Objective(s):

Upon completion of this unit the student will be able to:
a. Discuss the reasons for heat treating;
b. Discuss the time/temperature chart;
c. List the different quenching media;
d. Estimate metal heat temperature by color; and,
e. List reasons for stress relieving workpieces.

Instructional Materials:

MASTER Handout (CNC-D3-HO)
MASTER Self-Assessment
Samples of various metals that have been treated
Samples of the non-toxic treatment media

References:

Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition, "Hardening, Case Hardening, and Tempering" and "Annealing, Normalizing, and Stress Relieving"
Machinery's Handbook, Industrial Press, Latest Edition, Heat Treatment of Steel

Student Preparation:

Students should have previously completed the following Technical Modules:
CNC-D1 "Identify Materials with Desired Properties"
CNC-D2 "Identify Materials and Processes to Produce a Part"

Introduction:

Treating metals with rapid temperature changes to strengthen them is an ancient practice, dating back at least to the Eighth Century. Many archaeologists believe that the practice of *quenching* was greatly improved in Damascus about 700 AD purely by accident! It seems that the ruler of the city did not like the executions of criminals to be a messy, bloody spectacle. The Arabs already knew that wounds could be cauterized, and so the Emir ordered his executioner to heat his sword before each execution. The executioner soon discovered the difference in the sword, and it was not long before the practice spread. The first common quenching medium (other than plain water) was probably lamb's blood. Today, while there are much better media for quenching, the principle remains the same—certain chemicals, absorbed from the medium by the metal, change the strength of the part.

Presentation Outline:

I. Discuss the Reasons for Heat Treating
    A. Hardening for utility
    B. Tempering for toughness without brittleness
II. Discuss the Time/Temperature Chart
III. List the Different Quenching Media (In order of *severity* or speed of quenching)
    A. Brine (water and sodium chloride or sodium hydroxide)
    B. Water
    C. Fused (liquid) salts
    D. Molten lead
    E. Soluble oil and water
    F. Oil
    G. Air
IV. Estimate Metal Heat Temperature by Color
    A. Use of the temper color chart for tempering

Temperature (F)	Temperature (C)	Oxide Color	Suggested Uses
425	220	Light Straw	Steel-cutting tools
462	240	Dark Straw	Punches & Dies
490	258	Gold	Shear blades
500	260	Purple	Wood-cutting tools
540	282	Violet	Screwdrivers
580	304	Pale Blue	Springs
620	327	Steel Grey	None

    B. *Chicken Wire* markings warn of overheating.
V. List Reasons for Stress Relieving Workpieces
    A. Increased machinability

B. Increased workability in cold processes
VI. Special Safety Concerns of Heat Treating
    A. Protective Gear against. . .
        1. Heat
        2. Fumes
        3. Concussion
    B. Toxicity of Certain Media
VII. Special Problems in Heat Treating
    A. Brittleness
    B. Distortion
    C. Discoloration (sometimes unimportant)
    D. Inadvertant heat treating

Practical Application:

Students will be able to:
a. Safely handle metals during heat treatment;
b. Recognize and control problems involved in heat treatment;
c. Curtail inadvertent heat treatment;
d. Discuss the reasons for heat treating;
e. Use the time/temperature chart;
f. Recognize and use the different quenching media;
g. Estimate metal heat temperature by color; and,
h. List reasons for stress relieving workpieces.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-D4) dealing with the testing of metal samples for hardness.

CNC-D3-HO
Describe the Heat Treating Process
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Discuss the reasons for heat treating;
b. Discuss the time/temperature chart;
c. List the different quenching media;
d. Estimate metal heat temperature by color; and,
e. List reasons for stress relieving workpieces.

Module Outline:

I. Discuss the Reasons for Heat Treating
   A. Hardening for utility
   B. Tempering for toughness without brittleness
II. Discuss the Time/Temperature Chart
III. List the Different Quenching Media (In order of *severity* or speed of quenching)
   A. Brine (water and sodium chloride or sodium hydroxide)
   B. Water
   C. Fused (liquid) salts
   D. Molten lead
   E. Soluble oil and water
   F. Oil
   G. Air
IV. Estimate Metal Heat Temperature by Color
   A. Use of the temper color chart for tempering

Temperature (F)	Temperature (C)	Oxide Color	Suggested Uses
425	220	Light Straw	Steel-cutting tools
462	240	Dark Straw	Punches & Dies
490	258	Gold	Shear blades
500	260	Purple	Wood-cutting tools
540	282	Violet	Screwdrivers
580	304	Pale Blue	Springs
620	327	Steel Grey	None

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   - B. *Chicken Wire* markings warn of overheating.
- V. List Reasons for Stress Relieving Workpieces
   - A. Increased machinability
   - B. Increased workability in cold processes
- VI. Special Safety Concerns of Heat Treating
   - A. Protective Gear against. . .
      - 1. Heat
      - 2. Fumes
      - 3. Concussion
   - B. Toxicity of Certain Media
- VII. Special Problems in Heat Treating
   - A. Brittleness
   - B. Distortion
   - C. Discoloration (sometimes unimportant)
   - D. Inadvertent heat treating

Name_______________________ Date_______________

CNC-D3
Describe the Heat Treating Process
Self-Assessment

Circle the letter preceding the correct answer.

1. What is the approximate temperature required for stress relief annealing of low-carbon steels?
   - A. 950°
   - B. 1000°
   - C. 1950°
   - D. 1700°
   - E. None of the above answers is correct.

2. What crystalline processes result from stress relief annealing?
   - A. All grains reform into softer grains.
   - B. Distorted grains reform into softer grains.
   - C. Ferrite grains reform into softer grains while pearlite grains are basically unaffected.
   - D. Pearlite grains reform into softer grains while ferrite grains are basically unaffected.
   - E. None of the above answers is correct.

3. Which of the following is *not* a cause of quenching cracks?
   - A. Improper quenching medium
   - B. Overheating during the austenitizing cycle
   - C. Improper quenching angle
   - D. All of the above are causes of quenching cracks.
   - E. None of the above answers is correct.

4. Which of the following is *not* a characteristic of typical quench cracks?
   - A. The fracture tends to run from the surface toward the center in a smooth curve.
   - B. Untempered quench cracks will not show any decarburization.
   - C. Tempered fracture surfaces will show a fine crystalline structure.
   - D. All of the above are characteristic of quench cracks.
   - E. None of the above answers is correct.

5. During tempering by color, which of the following colors represents the highest temperature?
   A. Gold
   B. Purple
   C. Dark Straw
   D. Pale Blue
   E. Violet

6. During tempering by color, which of the following colors represents the lowest temperature?
   A. Gold
   B. Purple
   C. Dark Straw
   D. Pale Blue
   E. Violet

7. What is meant by *step quenching?*
   A. The workpiece is first quenched in a slow medium (e. g., air) then in a fast medium (e. g., water).
   B. The workpiece is first quenched in a fast medium (e. g., water) then in a slow medium (e. g., air).
   C. The weaker parts of the workpiece are quenched separately from the main body of the workpiece.
   D. The workpiece is lowered into the quenching medium in steps, so that different parts of the workpiece attain different hardnesses.
   E. None of the above answers is correct.

8. What is the simplest thing that the technician can do to minimize the vapor-blanket stage of liquid quenching?
   A. Agitate the workpiece or the medium.
   B. Heat the quenching medium to just below its boiling point.
   C. Quickly insert the workpiece into the medium.
   D. Slowly insert the workpiece into the medium.
   E. None of the above answers is correct.

9. Liquid carburizing, as used in case hardening, utilizes ___ and is therefor extremely dangerous.
   A. Sodium Chloride
   B. Calcium Carbonate
   C. Cyanide salts
   D. Ammonia
   E. None of the above answers is correct.

10. Workpieces which have been cut with an oxyacetylene torch often display edge hardness because:
    A. The torch was starved for oxygen.
    B. The workpiece was cut at too low a temperature.
    C. The wrong type of cutting torch was used.
    D. Oxyacetylene torches always leave hardened edges.
    E. None of the above answers is correct.

CNC-D3
Describe the Heat Treating Process
Self-Assessment Answer Key

1. A
2. C
3. D
4. A
5. C
6. D
7. B
8. A
9. C
10. A

CNC-D4

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-D4

Subject: **Advanced CNC and CAM** **Time: 8 Hrs.**

Duty: **Recognize Different Manufacturing Materials and Processes**
Task: Test Metal Samples for Hardness

Objective(s):

Upon completion of this unit the student will be able to:
a. Perform file test to test for metal hardness;
b. Use other tests to identify metals; and,
c. Perform Rockwell hardness tests.

Instructional Materials:

MASTER Handout (CNC-D4-HO)
MASTER Laboratory Exercise (CNC-D4-LE)
MASTER Laboratory Aid (CNC-D4-LA)
MASTER Self-Assessment
Several samples of various metals (including one aluminum and one magnesium)
Rockwell hardness tester
Grinder
New files (one per student)
Safety glasses or face shields (one per student)
Copper sulfate or zinc chloride solution

References:

Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition, "Selection & Identification of Steels and Rockwell & Brinell Hardness Testers"

Student Preparation:

Students should have previously completed the following Technical Modules:
CNC-D1 "Identify Materials with Desired Properties"
CNC-D2 "Identify Materials and Processes to Produce a Part"
CNC-D3 "Describe the Heat Treating Process"

Introduction:

Hardness is surface resistance to deformation. It is not tensile strength; although a mathematical relationship between the two is relevant to machining and metal working in general.

Presentation Outline:

I. Perform File Test to Test for Metal Hardness
    A. Imprecise method, good for rough estimates only
    B. Requires more experienced machinist
II. Use Other Tests to Identify Metals
    A. High-carbon steels show more spark bursts than do low-carbon steels.
    B. Non-ferrous metals
        1. Aluminum
        2. Magnesium
        3. Brass
        4. Bronze
        5. Nickel
        6. Tin
        7. Others
III. Perform Rockwell Hardness Tests
    A. Ferrous metals
    B. Non-ferrous metals
IV. Perform Brinell Hardness Tests
    A. Ferrous metals
    B. Non-ferrous metals
V. Other Hardness Tests as Specified by the Instructor
    A. Ferrous metals
    B. Non-ferrous metals

Practical Application:

The student will complete the laboratory assignment (CNC-D4-LE).

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-D5) dealing with different welding operations.

CNC-D4-HO
Test Metal Samples for Hardness
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:

- a. Perform file test to test for metal hardness;
- b. Use other tests to identify metals; and,
- c. Perform Rockwell hardness tests.

Module Outline:

- I. Perform File Test to Test for Metal Hardness
  - A. Imprecise method, good for rough estimates only
  - B. Requires more experienced machinist
- II. Use Other Tests to Identify Metals
  - A. High-carbon steels show more spark bursts than do low-carbon steels.
  - B. Non-ferrous metals
    - 1. Aluminum
    - 2. Magnesium
    - 3. Brass
    - 4. Bronze
    - 5. Nickel
    - 6. Tin
    - 7. Others
- III. Perform Rockwell Hardness Tests
  - A. Ferrous metals
  - B. Non-ferrous metals
- IV. Perform Brinell Hardness Tests
  - A. Ferrous metals
  - B. Non-ferrous metals
- V. Other Hardness Tests as Specified by the Instructor
  - A. Ferrous metals
  - B. Non-ferrous metals

CNC-D4-LE
Test Metal Samples for Hardness
Attachment 2: **MASTER** Laboratory Exercise

I. The instructor should demonstrate the aluminum/magnesium test using the zinc chloride solution.
II. Each student should receive eye or full face protection and three to five samples for evaluation.
III. Each sample should be file-tested.
IV. Each sample should be spark-tested.
V. Each sample should be tested for hardness on the Rockwell tester.

RESULTS OF TESTS

Record your answers on the following charts. Under "Characteristics," write what you saw (spark length, color, etc.) or felt (resistance, heating, etc.) during the test.

FILE TEST

Sample	Characteristics	Preliminary Identification
1		
2		
3		
4		
5		

SPARK TEST

Sample	Characteristics	Preliminary Identification
1		
2		
3		
4		
5		

ROCKWELL HARDNESS TEST

Sample	Rockwell Hardness Number	Preliminary Identification
1		
2		
3		
4		
5		

BRINELL HARDNESS TEST

Sample	Brinell Hardness Number	Preliminary Identification
1		
2		
3		
4		
5		

OTHER HARDNESS TEST

Sample	Hardness Designation	Preliminary Identification
1		
2		
3		
4		
5		

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

Name____________________________ Date________________

CNC-D4
Test Metal Samples for Hardness
Self-Assessment

Circle the letter preceding the correct answer.

1. The *hardness* of a metal is its ability to resist:
   - A. Permanent deformation.
   - B. Oxidation.
   - C. Chemical reaction.
   - D. All of the above answers are forms of hardness.
   - E. None of the above answers is correct.

2. Rockwell testing machines test the sample metal's resistance to:
   - A. Abrasion.
   - B. Penetration.
   - C. Elastic deformation.
   - D. Electricity.
   - E. None of the above answers is correct.

3. Materials such as nitrided steel and hard cast irons generally have Rockwell hardness numbers in excess of:
   - A. B-50.
   - B. B-75.
   - C. B-100.
   - D. B-150.
   - E. None of the above answers is correct.

4. During the file test, if the file will mark the metal but not cut into it, then the metal should be treated as:
   - A. High-alloy steel.
   - B. Mild steel.
   - C. Hardened tool steel.
   - D. Medium-carbon steel.
   - E. None of the above answers is correct.

5. Probably the best use of the spark test is to:
   - A. Determine the alloy content of the sample.
   - B. Identify cast iron.
   - C. Compare the sample to a known piece.
   - D. All of the above answers are valid.
   - E. None of the above answers is correct.

6. Tool steel has a Rockwell hardness of ___, while hardened tool steel has hardness number of ___.
A. C-42. . .C-64
B. C-42. . .B-65
C. C-64. . .C-42
D. B-65. . .C-42
E. None of the above answers is correct.

7. Which of the following surfaces should be avoided when hardness testing?
A. Curved
B. Rough
C. Decarburized
D. All of the above surfaces should be modified before testing the sample's hardness.
E. None of the above answers is correct.

8. For hardness testing, the minimum recommended clearance from the edge is:
A. ½"
B. 1/4"
C. 1/8"
D. 1/16"
E. None of the above answers is correct.

9. If a Rockwell tester is in daily use, it should be calibrated:
A. Annually.
B. Monthly.
C. Weekly.
D. Daily.
E. Never.

10. Technician A says that, for large samples, multiple hardness test should be made and their results averaged. Technician B says that many materials vary in hardness over the length of the sample. Who is correct?
A. Technician A only
B. Technician B only
C. Both technicians are correct.
D. Neither technician is correct.

CNC-D4
Test Metal Samples for Hardness
Self-Assessment Answer Key

1. A
2. B
3. C
4. C
5. C
6. E
7. D
8. C
9. D
10. D

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-D5

Subject: **Advanced CNC and CAM** **Time: 20 Hrs.**

Duty: **Recognize Different Manufacturing Materials and Processes**
Task: Understand Welding Operations

Objective(s):

Upon completion of this unit the student will be able to:
a. Perform the basic SMAW process;
b. Perform the basic oxyacetylene cutting and welding process;
c. Perform the basic GTAW (Heliarc) process; and,
d. Perform the basic GMAW (MIG) process.

Instructional Materials:

MASTER Handout (CNC-D5-HO)
MASTER Laboratory Exercise (CNC-D5-LE)
MASTER Laboratory Aid (CNC-D5-LA)
MASTER Self-Assessment
Basic hand tools
Chipping hammer
Clear welding lens
Constant-current welding machine
Ground cable and clamp
Metal samples for cutting and welding
Safety glasses
Various small welders
Welding gloves
Welding helmet
Welding lens (#7 - 14)
Wire brush

References:

Oxy-Acetylene Handbook, Linde, Union Carbide Publisher, Latest Edition
New Lessons in Arc Welding, Lincoln Electric, Lincoln Electric Publishers, Latest Edition

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Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-D1	"Identify Materials with Desired Properties"
CNC-D2	"Identify Materials and Processes to Produce a Part"
CNC-D3	"Describe the Heat Treating Process"
CNC-D4	"Test Metal Samples for Hardness"

Introduction:

Welding is an important, if dangerous, part of the machinist's life. Welding operations are used to cut, repair, and fabricate almost daily. Proper use of the welding torch and its accompanying safety equipment is critical to the machining industry.

Presentation Outline:

DON'T CARRY A BOMB IN YOUR POCKET!

NEVER carry a butane lighter into a welding area. These are mini-Molotov cocktails.

I. Safety Procedures Specific to the Welding Process
  A. Specific safety precautions must be taken to ensure a proper breathing atmosphere in all welding areas.
    1. Weld only in ventilated areas. Welding shielding gases can displace the air needed for breathing. These gases are odorless and colorless, and most are heavier than air.
    2. Weld in a position that will allow your head to be out of the welding plume, but will still give a good view of the welding arc. The welding plume could contain harmful fumes and gases.
    3. Provide enough ventilation wherever welding and cutting are performed. Welding in confined spaces may require special procedures, such as the use of an air-supplied hood or hose mask.
    4. Do not weld on dirty plate or plate contaminated with an unknown material. The fumes and gases which are formed could be hazardous to health.
  B. Electrical shock can be avoided by following specific safety precautions.
    1. Do not touch live electrical parts.
    2. Ground all electrical equipment and the work-piece to prevent accidental electrical shocks.
    3. Use the correct welding cable size for both the ground lead and the welding lead. Sustained overloading will cause cable failure and result in possible electrical shock or fire hazard.

4. Be sure all electrical connections are tight, clean, and dry. Poor electrical connections can heat up and even melt, causing dangerous arcs and sparks.
5. Keep dry. Moisture and water can conduct electricity. Fix water leaks immediately.
6. Keep welding cables and connectors in good condition. Improper or worn electrical connections can cause short circuits and can increase the chance of an electrical shock.
7. Avoid open-circuit voltage. Open-circuit voltage is much higher than welding voltage.
8. Shut off electrical power when working on welding equipment.

C. Ultraviolet and infrared rays emitted by the welding arc, as well as the spatter from the welding arc, can injure eyes and burn skin. Specific safety precautions must be followed to ensure adequate protection.

1. Wear 100% cotton clothing. It will not catch fire easily, it offers good protection from light welding spatter, and it is cooler in the summer and warmer in the winter.
2. Cover all skin surfaces. Keep shirt sleeves rolled down.
3. Wear cuffless pants to eliminate spatter traps.
4. Wear leather boots. Pant legs should cover boot tops.
5. Wear clean clothing. Oil- and grease-stained clothes will tend to ignite from welding spatter.
6. For more severe welding conditions, wear protective clothing such as heat resistant jackets, aprons, and leggings.
7. Wear safety glasses to protect from arc flashes, mechanical injury, or other mishaps.
8. Wear ear protection, not only where there is noise but where there is a chance that spatter or sparks could get into the ears.
9. Wear a 100% cotton cap to protect the head from sparks or spatter.
10. Wear long-gauntlet leather gloves.
11. Do not touch hot metal with bare hands. Use tongs or pliers and wear leather gloves.
12. Protect nearby workers from exposure to the welding arc by putting up shields.
13. Wear a welding helmet with the correct shade of welding lens. Choose the correct lens from a filter recommendations table (See Figure 1).

FILTER RECOMMENDATIONS
(adapted from ANSI Safety Standard Z49.1-88)
SMAW

Application	Minimum Shade No.	Suggested Shade*
Less than 60 amps	7	9
60 to 160 amps	8	10
160 to 250 amps	10	12
250 to 500 amps	11	14

* As a general rule, start with a shade that is too dark to see the arc zone. Then go to the next lighter shade until you find one which gives you sufficient view of the arc zone without exerting a strain on your eyes.

Figure 1 Filter Recommendations

D. Specific precautions must be taken to ensure that there is no loss of property due to welding sparks, spatter, and heat.
   1. If possible, weld in specially designated areas or enclosures of noncombustible construction.
   2. Remove combustibles from the work area by at least 35 feet if possible.
   3. Cover combustibles that cannot be removed from the welding area with tight-fitting, flame-resistant material. Items that should be covered include combustible walls, floors, ceilings, and any cracks or other openings that might let a spark pass through it.
   4. If welding is to be performed on or adjacent to a metal wall, ceiling, or partition, move combustibles on the other side to a safe location.
   5. If combustibles cannot be adequately sealed off or removed, station a fire watcher at that location. The fire watcher must have adequate fire extinguishing capabilities.
   6. Do not weld on materials having either a coating or internal structure that is combustible.
   7. Place hot scrap and slag in non-combustible containers.
   8. Ensure that fire extinguishers are available nearby.

9. Conduct a thorough examination for evidence of a fire before leaving the work area, and continue a fire check for at least 30 minutes after the welding operation has been completed.
10. Follow all company safety procedures regarding welding in hazardous areas.

E. Specific Safety Precautions for Oxyacetylene Equipment

CAUTION: Specific preventive and protective safety measures must be followed when using oxyacetylene equipment:

1. Use goggles or shield with a number five shade.
2. Wear gloves, long sleeve shirts, pants of high cotton or wool content, leather boots, and soft cotton caps.
3. When lighting the torch, direct the torch away from yourself and other personnel.
4. Never leave a lit torch unattended. When leaving your work station, always extinguish your torch.
5. Never use matches or butane lighters for lighting a torch. Only use spark or friction lighters.
6. Never cut on containers that have contained flammable or toxic substances.
7. Either move work away from or protect wooden or other flammable materials which may be close to the work.
8. When cutting, cover concrete floors with sheet metal where sparks and molten metal are being directed.
9. Before beginning to work, locate the nearest fire alarm and the nearest fire extinguisher.
10. Cut in a well-ventilated area. If adequate ventilation is not possible, use a respirator.
11. Keep all petroleum products away from oxyacetylene equipment and operations. The combination of pure oxygen and oil is explosive.

F. Specific Safety Precautions for Acetylene and Oxygen Cylinders

CAUTION: Handle acetylene and oxygen cylinders carefully:

1. Keep acetylene operating pressures at or below 15 psi.
2. Open the acetylene cylinder valve one-half to one full turn when using a portable rig to be sure that the cylinder can be quickly turned off in the event of burn-back or a fire at a leak in the hose or at a connection.
3. Do not open the acetylene torch valve where acetylene could flow into a bucket or other container and cause a fire.
4. Never attempt to connect an acetylene hose to an oxygen torch connection. Damage to the torch or an explosion could result. Acetylene hoses are colored red and acetylene fittings are left-hand threaded and usually notched.
5. Never use oxygen or fuel gas from a cylinder except through an approved pressure-reducing regulator.

6. Do not use pipe-fitting compounds or thread lubricants for making connections.
7. Never use a cylinder that is leaking.
8. Store and transport cylinders in the upright position.
9. Secure all cylinders with chain when storing, transporting, or using, to prevent them from being turned over by accident.
10. Never tamper with fusible plugs or other safety devices on cylinders.
11. To open and close acetylene cylinder valves not provided with hand-wheels, always use the special wrench or key. When cutting, leave the key in place for rapid shutdown in case of fire.
12. Never use any cylinder, full or empty, as a roller or support.
13. Never use oxygen as though it were compressed air.
14. Do not handle oxygen cylinders on the same platform with oil.
15. Never use wire-rope slings or electromagnets for lifting cylinders. Do not lift cylinders by the protective cap alone.
16. Store oxygen cylinders separately from fuel gas cylinders.
17. Always keep empty cylinders separate from full cylinders.
18. Mark all empty cylinders as such after use.
19. Keep all cylinders stored inside buildings at least 20 feet away from combustible materials.
20. Never bring any arc or flame close to or directly into contact with a cylinder.
21. Never exceed the maximum safe withdrawal rate for acetylene cylinders (one seventh of the cylinder's *current* contents per hour). If acetylene is withdrawn from the cylinder at a greater rate, acetone will also be withdrawn from the cylinder, damaging the cutting equipment. If additional flow is needed, then manifold the required number of cylinders together.

G. Specific Safety Precautions for Regulator Burnout (R.B.O.)

CAUTION: Avoid potentially deadly regulator burnout (R.B.O.). Regulator burnout is a spontaneous explosion that happens when a torch is being lit. To minimize the risk of R.B.O., follow these safety precautions:

1. "Crack" the oxygen cylinder valve (open it slightly) before attaching the regulator. Stand to one side or the rear of the cylinder outlet. Open the cylinder valve slightly for an instant and then close it to clean the valve of dust and dirt which may have accumulated during storage. Dirt can damage an oxygen regulator and may cause R.B.O.
2. Use only oxygen regulators to control oxygen supply. A pressure-reducing regulator must be connected to the oxygen cylinder valve. Make certain the regulator is clean, free of grease and oil, and has a clean filter installed in its inlet nipple.

Oil, grease, coal dust, and other combustibles can cause regulator burnouts. Never use an oxygen regulator for other gases.

3. Before opening an oxygen cylinder valve, make sure the oxygen regulator pressure-adjusting screw is released. This is done by rotating the screw counterclockwise until it turns freely. This closes the regulator valve and prevents damage due to a sudden pressure surge.
4. While opening the oxygen cylinder valve, stand to one side of the oxygen regulator. Do not stand in line with the front or the back of the pressure-adjusting screw. Open the cylinder valve as slowly as possible, until the high pressure gauge reaches cylinder pressure. Never open a cylinder valve suddenly. Sudden surges of high pressure can cause R.B.O.

II. Describe the SMAW Process

Shielded Metal Arc Welding is a welding process which joins metals by heating them with an arc between a covered metal electrode and the metals being joined. Shielding is obtained from the decomposition (breakdown) of the electrode covering. Pressure is not used and filler metal is obtained from the electrode. The electric arc flowing across an air gap produces very intense heat and light. An electric arc has been measured at 10,000°F. Considering that steel melts at around 2800°F, the electric arc is indeed a very fast and efficient heat source for melting steel when welding.

III. Describe the Oxyacetylene Cutting and Welding Process

Oxyacetylene cutting requires the use of specific procedures and specific techniques in order to work safely and to produce acceptable cuts. Proper flame adjustments, torch angles, and flame-to-work distances must be maintained in order to produce good cuts. Oxyacetylene cutting can be done from both fixed cutting stations and from portable cutting stations.

The key operations to oxyacetylene cutting are as follows:

1. Prepare to cut.
2. Light the torch.
3. Cut metal with the torch.
4. Extinguish the torch.

HOW TO SELECT THE CORRECT NUMBER OF ACETYLENE CYLINDERS

To determine the number of cylinders required for proper manifold operation, follow the guidelines below:

1. The number of cylinders in the manifold is determined by the volume of gas in cubic feet per hour required. Determine the cubic feet per hour required for the largest tip used and multiply that by the number of torches or stations in operation at the same time. This will give the total volume of each gas required per hour.
2. The manifold should have enough cylinders to provide a minimum of one day's requirements.
3. Maximum acetylene withdrawal for continuous operation is 1/7 (of 14%) of each cylinder capacity per hour. The chart allows for 7.8% excess capacity.

CFH acetylene withdrawal per hour required	Number of 300 cubic foot cylinders per manifold
40	1
80	2
120	3
160	4
200	5
240	6
280	7
320	8
360	9
400	10
440	11
480	12
520	13
560	14
600	15
640	16
680	17
720	18
760	19
800	20

Acetylene Cylinder Manifold Guide

IV. Describe the GTAW (Heliarc) Process
V. Describe the GMAW (MIG) Process
VI. Describe the Band/Flash Welding Machine and Process

Practical Application:

The student will be able to perform minor welding repairs.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-E1) dealing with understanding metrology terms.

CNC-D5-HO
Understand Welding Operations
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Perform the basic SMAW process;
b. Perform the basic oxyacetylene cutting and welding process;
c. Perform the basic GTAW (Heliarc) process; and,
d. Perform the basic GMAW (MIG) process.

Module Outline:

DON'T CARRY A BOMB IN YOUR POCKET!

NEVER carry a butane lighter into a welding area. These are mini-Molotov cocktails.

I. Safety Procedures Specific to the Welding Process
   A. Specific safety precautions must be taken to ensure a proper breathing atmosphere in all welding areas.
      1. Weld only in ventilated areas. Welding shielding gases can displace the air needed for breathing. These gases are odorless and colorless, and most are heavier than air.
      2. Weld in a position that will allow your head to be out of the welding plume, but will still give a good view of the welding arc. The welding plume could contain harmful fumes and gases.
      3. Provide enough ventilation wherever welding and cutting are performed. Welding in confined spaces may require special procedures, such as the use of an air-supplied hood or hose mask.
      4. Do not weld on dirty plate or plate contaminated with an unknown material. The fumes and gases which are formed could be hazardous to health.
   B. Electrical shock can be avoided by following specific safety precautions.
      1. Do not touch live electrical parts.
      2. Ground all electrical equipment and the work-piece to prevent accidental electrical shocks.
      3. Use the correct welding cable size for both the ground lead and the welding lead. Sustained overloading will cause cable failure and result in possible electrical shock or fire hazard.

4. Be sure all electrical connections are tight, clean, and dry. Poor electrical connections can heat up and even melt, causing dangerous arcs and sparks.
5. Keep dry. Moisture and water can conduct electricity. Fix water leaks immediately.
6. Keep welding cables and connectors in good condition. Improper or worn electrical connections can cause short circuits and can increase the chance of an electrical shock.
7. Avoid open-circuit voltage. Open-circuit voltage is much higher than welding voltage.
8. Shut off electrical power when working on welding equipment.

C. Ultraviolet and infrared rays emitted by the welding arc, as well as the spatter from the welding arc, can injure eyes and burn skin. Specific safety precautions must be followed to ensure adequate protection.

1. Wear 100% cotton clothing. It will not catch fire easily, it offers good protection from light welding spatter, and it is cooler in the summer and warmer in the winter.
2. Cover all skin surfaces. Keep shirt sleeves rolled down.
3. Wear cuffless pants to eliminate spatter traps.
4. Wear leather boots. Pant legs should cover boot tops.
5. Wear clean clothing. Oil- and grease-stained clothes will tend to ignite from welding spatter.
6. For more severe welding conditions, wear protective clothing such as heat resistant jackets, aprons, and leggings.
7. Wear safety glasses to protect from arc flashes, mechanical injury, or other mishaps.
8. Wear ear protection, not only where there is noise but where there is a chance that spatter or sparks could get into the ears.
9. Wear a 100% cotton cap to protect the head from sparks or spatter.
10. Wear long-gauntlet leather gloves.
11. Do not touch hot metal with bare hands. Use tongs or pliers and wear leather gloves.
12. Protect nearby workers from exposure to the welding arc by putting up shields.
13. Wear a welding helmet with the correct shade of welding lens. Choose the correct lens from a filter recommendations table (See Figure 1).

FILTER RECOMMENDATIONS
(adapted from ANSI Safety Standard Z49.1-88)
SMAW

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* As a general rule, start with a shade that is too dark to see the arc zone. Then go to the next lighter shade until you find one which gives you sufficient view of the arc zone without exerting a strain on your eyes.

FIGURE 1 FILTER RECOMMENDATIONS

D. Specific precautions must be taken to ensure that there is no loss of property due to welding sparks, spatter, and heat.

1. If possible, weld in specially designated areas or enclosures of noncombustible construction.
2. Remove combustibles from the work area by at least 35 feet if possible.
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4. If welding is to be performed on or adjacent to a metal wall, ceiling, or partition, move combustibles on the other side to a safe location.
5. If combustibles cannot be adequately sealed off or removed, station a fire watcher at that location. The fire watcher must have adequate fire extinguishing capabilities.
6. Do not weld on materials having either a coating or internal structure that is combustible.
7. Place hot scrap and slag in non-combustible containers.
8. Ensure that fire extinguishers are available nearby.

9. Conduct a thorough examination for evidence of a fire before leaving the work area, and continue a fire check for at least 30 minutes after the welding operation has been completed.
10. Follow all company safety procedures regarding welding in hazardous areas.

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4. Never leave a lit torch unattended. When leaving your work station, always extinguish your torch.
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6. Never cut on containers that have contained flammable or toxic substances.
7. Either move work away from or protect wooden or other flammable materials which may be close to the work.
8. When cutting, cover concrete floors with sheet metal where sparks and molten metal are being directed.
9. Before beginning to work, locate the nearest fire alarm and the nearest fire extinguisher.
10. Cut in a well-ventilated area. If adequate ventilation is not possible, use a respirator.
11. Keep all petroleum products away from oxyacetylene equipment and operations. The combination of pure oxygen and oil is explosive.

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CAUTION: Handle acetylene and oxygen cylinders carefully:

1. Keep acetylene operating pressures at or below 15 psi.
2. Open the acetylene cylinder valve one-half to one full turn when using a portable rig to be sure that the cylinder can be quickly turned off in the event of burn-back or a fire at a leak in the hose or at a connection.
3. Do not open the acetylene torch valve where acetylene could flow into a bucket or other container and cause a fire.
4. Never attempt to connect an acetylene hose to an oxygen torch connection. Damage to the torch or an explosion could result. Acetylene hoses are colored red and acetylene fittings are left-hand threaded and usually notched.
5. Never use oxygen or fuel gas from a cylinder except through an approved pressure-reducing regulator.

6. Do not use pipe-fitting compounds or thread lubricants for making connections.
7. Never use a cylinder that is leaking.
8. Store and transport cylinders in the upright position.
9. Secure all cylinders with chain when storing, transporting, or using, to prevent them from being turned over by accident.
10. Never tamper with fusible plugs or other safety devices on cylinders.
11. To open and close acetylene cylinder valves not provided with hand-wheels, always use the special wrench or key. When cutting, leave the key in place for rapid shutdown in case of fire.
12. Never use any cylinder, full or empty, as a roller or support.
13. Never use oxygen as though it were compressed air.
14. Do not handle oxygen cylinders on the same platform with oil.
15. Never use wire-rope slings or electromagnets for lifting cylinders. Do not lift cylinders by the protective cap alone.
16. Store oxygen cylinders separately from fuel gas cylinders.
17. Always keep empty cylinders separate from full cylinders.
18. Mark all empty cylinders as such after use.
19. Keep all cylinders stored inside buildings at least 20 feet away from combustible materials.
20. Never bring any arc or flame close to or directly into contact with a cylinder.
21. Never exceed the maximum safe withdrawal rate for acetylene cylinders (one seventh of the cylinder's *current* contents per hour). If acetylene is withdrawn from the cylinder at a greater rate, acetone will also be withdrawn from the cylinder, damaging the cutting equipment. If additional flow is needed, then manifold the required number of cylinders together.

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2. Use only oxygen regulators to control oxygen supply. A pressure-reducing regulator must be connected to the oxygen cylinder valve. Make certain the regulator is clean, free of grease and oil, and has a clean filter installed in its inlet nipple.

Oil, grease, coal dust, and other combustibles can cause regulator burnouts. Never use an oxygen regulator for other gases.

3. Before opening an oxygen cylinder valve, make sure the oxygen regulator pressure-adjusting screw is released. This is done by rotating the screw counterclockwise until it turns freely. This closes the regulator valve and prevents damage due to a sudden pressure surge.
4. While opening the oxygen cylinder valve, stand to one side of the oxygen regulator. Do not stand in line with the front or the back of the pressure-adjusting screw. Open the cylinder valve as slowly as possible, until the high pressure gauge reaches cylinder pressure. Never open a cylinder valve suddenly. Sudden surges of high pressure can cause R.B.O.

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The key operations to oxyacetylene cutting are as follows:

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4. Extinguish the torch.

HOW TO SELECT THE CORRECT NUMBER OF ACETYLENE CYLINDERS

To determine the number of cylinders required for proper manifold operation, follow the guidelines below:

1. The number of cylinders in the manifold is determined by the volume of gas in cubic feet per hour required. Determine the cubic feet per hour required for the largest tip used and multiply that by the number of torches or stations in operation at the same time. This will give the total volume of each gas required per hour.
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3. Maximum acetylene withdrawal for continuous operation is 1/7 (of 14%) of each cylinder capacity per hour. The chart allows for 7.8% excess capacity.

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Acetylene Cylinder Manifold Guide

IV. Describe the GTAW (Heliarc) Process
V. Describe the GMAW (MIG) Process
VI. Describe the Band/Flash Welding Machine and Process

CNC-D5-LE
Understand Welding Operations
Attachment 2: MASTER Laboratory Exercise

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1. The instructor will demonstrate each of the following processes:
   a. Basic SMAW process;
   b. Basic oxyacetylene cutting and welding process;
   c. Basic GTAW (Heliarc) process; and,
   d. Basic GMAW (MIG) process.

2. The students will practice each of the following processes:
   a. Basic SMAW process;
   b. Basic oxyacetylene cutting and welding process;
   c. Basic GTAW (Heliarc) process; and,
   d. Basic GMAW (MIG) process.

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
   a. No loose clothing, including ties;
   b. Long hair properly stowed;
   c. No jewelry;
   d. Hard, closed-toe shoes;
   e. Eye protection (safety glasses); and,
   f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

Name______________________________ Date_______________

CNC-D5
Understand Welding Operations
Self-Assessment

Circle the letter preceding the correct answer.

1. Technician A says that they can cut into an old water can with the torch. Technician B says that containers of flammable or toxic substances should never be cut with a torch. Who is correct?
   A. Technician A only
   B. Technician B only
   C. Both Technicians A and B
   D. Neither Technician A nor B

2. Before attaching the regulators to the cylinder valves:
   A. Clean the nipples with acetone.
   B. Crack the valves to blow out any dirt.
   C. Lubricate the threads with oil.
   D. All of the above
   E. None of the above

3. Technician A says that since B is left-handed, B should cut from left to right. Technician B says that the pre-heat flame should still be from 1/6" to ½" from the base metal, regardless of the direction of travel. Who is correct?
   A. Technician A only
   B. Technician B only
   C. Both Technicians A and B
   D. Neither Technician A nor B

4. If adequate ventilation is unavailable, the technician should:
   A. Cut the metal anyway; ventilation is not important.
   B. Cut the metal while wearing a respirator.
   C. Cut the metal while wearing a heavy-duty dust mask.
   D. Refuse to make the cut.

5. Technician A says that they must reduce the acetylene flow until the flame just starts to produce black smoke around its edges. Technician B says that the acetylene flow must then be increased until the smoke disappears. Who is correct?
   A. Technician A only
   B. Technician B only
   C. Both Technicians A and B
   D. Neither Technician A nor B

6. Acetylene operating pressures must be kept at or below:
   - A. 5 psi
   - B. 15 psi
   - C. 25 psi
   - D. Acetylene operating pressures are immaterial.

7. Dirty orifices on the cutting tip can produce:
   - A. Wide kerfs.
   - B. Adherent slag.
   - C. Rough cut appearance.
   - D. All of the above.
   - E. None of the above

8. Acetylene hoses are ___; acetylene fittings are ___.
   - A. Red . . . left-handed
   - B. Blue . . . left-handed
   - C. Red . . . right-handed
   - D. Blue . . . left-handed

9. Technician A says that, for cutting holes, the torch must be held parallel to the base metal throughout the cut. Technician B says that square cuts require the torch to be held at 45° to the base metal. Who is correct?
   - A. Technician A only
   - B. Technician B only
   - C. Both Technicians A and B
   - D. Neither Technician A nor B

10. Lag lines are the result of:
    - A. Correct travel speed.
    - B. Too great a travel speed.
    - C. Too slow a travel speed.
    - D. Incorrect torch angle.
    - E. None of the above

11. All cylinders should be secured except when:
    - A. Transporting them.
    - B. Storing them.
    - C. Using them.
    - D. Always secure cylinders with chains or in permanent racks.
    - E. Securing cylinders is unnecessary.

12. Technician A says that the acetylene cylinder's valve should be opened all the way. Technician B says that the oxygen cylinder's valve should be opened no more than one full turn. Who is correct?
    A. Technician A only
    B. Technician B only
    C. Both Technicians A and B
    D. Neither Technician A nor B

13. Which of the following can be used to ignite an oxyacetylene torch?
    A. Matches
    B. A cigarette lighter
    C. A spark or friction lighter
    D. Any of the above
    E. None of the above

14. Both acetylene and oxygen lines should be ___ when closing down the work station.
    A. Removed
    B. Cleaned with acetone
    C. Bled free of gas or fuel
    D. All of the above

15. Technician A says that only oxygen-specific regulators can be used on oxygen cylinders. Technician B says that it is acceptable to use oxygen regulators on other gas cylinders. Who is correct?
    A. Technician A only
    B. Technician B only
    C. Both Technicians A and B
    D. Neither Technician A nor B

16. When extinguishing the torch, Technician A says that the acetylene torch valve should be closed first. Technician B says that the oxygen torch valve should be closed first. Who is correct?
    A. Technician A only
    B. Technician B only
    C. Both Technicians A and B
    D. Neither Technician A nor B

17. Good oxy-fuel cuts require an oxygen purity of at least:
    A. 99.5%.
    B. 95.9%.
    C. 59.9%.
    D. None of the above is correct.

18. Technician A says that oxygen cylinders should be stored well away from fuel gas cylinders. Technician B says that separate storage is unnecessary. Who is correct?
    A. Technician A only
    B. Technician B only
    C. Both Technicians A and B
    D. Neither Technician A nor B

19. The maximum safe withdrawal rate for acetylene cylinders is:
    A. One fourth of current content per hour.
    B. One fifth of current content per hour.
    C. One seventh of current content per hour.
    D. One tenth of current content per hour.

20. Which of the following *can* be cut with an oxy-acetylene torch?
    A. Aluminum
    B. Copper
    C. Chromium
    D. All of the above
    E. None of the above

CNC-D5
Understand Welding Operations
Self-Assessment Answer Key

1.	C
2.	B
3.	C
4.	B
5.	C
6.	B
7.	D
8.	A
9.	D
10.	B
11.	D
12.	D
13.	C
14.	C
15.	A
16.	A
17.	A
18.	A
19.	C
20.	E

CNC MACHINIST .... **programs, edits, sets up, and operates CNC lathes, mills and grinders to perform machining operations necessary to produce workpieces to referenced engineering standards.**

	Duties	← Tasks →												
A	Practice Safety	A-1 Follow safety manuals and all safety regulations/ requirements	A-2 Use protective equipment	A-3 Follow safe operating procedures for hand and machine tools	A-4 Maintain a clean and safe work environment	A-5 MSDS/ control chemical hazards								
B	Apply Mathematical Concepts	B-1 Perform basic arithmetic functions	B-2 Convert fractions/ decimals	B-3 Convert Metric/ English measurements	B-4 Perform basic algebraic operations	B-5 Use practical geometry	B-6 Understand basic trigonometry	B-7 Calculate speeds and feeds for machining	B-8 Use coordinate systems					
C	Interpret Engineering Drawings and Control Documents	C-1 Identify basic layout of drawings	C-2 Identify basic types of drawings	C-3 Review blueprint notes and dimensions	C-4 List the purpose of each type of drawing	C-5 Verify drawing elements	C-6 Practice Geometric Dimensioning and Tolerancing (GD&T)	C-7 Analyze bill of materials (BOM)	C-8 Describe the relationship of engineering drawings to planning	C-9 Understand and use quality systems	C-10 Verify standard requirements			
D	Recognize Different Manufacturing Materials and Processes	D-1 Identify materials with desired properties	D-2 Identify materials and processes to produce a part	D-3 Describe the heat treating process	D-4 Test metal samples for hardness	D-5 Understand welding operations								
E	Measure/ Inspect	E-1 Understand metrology terms	E-2 Select measurement tools	E-3 Measure with hand held instruments	E-4 Eliminate measurement variables	E-5 Measure/ inspect using surface plate and accessories	E-6 Inspect using stationary equipment							
F	Perform Conventional Machining	F-1 Prepare and plan for machining operations	F-2 Use hand tools	F-3 Operate power saws	F-4 Operate drill presses	F-5 Operate vertical milling machines	F-6 Operate horizontal milling machines	F-7 Operate metal cutting lathes	F-8 Operate grinding/ abrasive machines					
G	Perform Advanced Machining	G-1 Understand CNC basics	G-2 Program CNC machines	G-3 Operate CNC machining centers (mills)	G-4 Operate CNC turning centers (lathes)									
H	Use Verification and Communication Systems	H-1 Use personal computer	H-2 Use various operating systems	H-3 Use computer communications systems	H-4 Use verification systems	H-5 Use the Internet								
I	Program Using CAM System	I-1 Understand CAD/ CAM programs	I-2 Manipulate CAD functions	I-3 Process simple tool-path data	I-4 Create advanced surface models	I-5 Process complex tool-path functions								

CNC-E1

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-E1

Subject: **Advanced CNC and CAM** **Time: 2 Hrs.**

Duty: **Measure/Inspect**
Task: Understand Metrology Terms

Objective(s):

Upon completion of this unit the student will be able to:

a. Discuss the use of metrology in manufacturing;
b. Discuss the Inch system of measurement;
c. Discuss the Metric system of measurement;
d. Discuss semi-precision and precision measurement; and,
e. Discuss the following: precision, reliability, discrimination, and accuracy.

Instructional Materials:

MASTER Handout (CNC-E1-HO)
MASTER Self-Assessment
As many different measurement instruments in both English and metric as is practical

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References:

Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition, "Dimensional Measurement"
NTMA Modules:
  MA-I-35 "Fractions"
  MA-II-05 "Metric Measurement"

Student Preparation:

Students should have previously completed the following Technical Modules:
  CNC-B1 "Perform Basic Arithmetic Functions"
  CNC-B2 "Convert Fractions/Decimals"
  CNC-B3 "Convert Metric/English Measurements"

Introduction:

The world has depended on some form of measurement system since the beginning of civilization. Measurement has progressed through many forms down through the years. Measurement is now referred to as metrology and has, by necessity, become an exact science because of the high degrees of precision required by manufactures and consumers today. Interchangeable manufacture, world trade, and the need for high precision have all contributed to the need for a highly accurate international system of measurement.

Presentation Outline:

- I. Discuss the Use of Metrology in Manufacturing
  - A. Discuss the function and reason for measurements in manufacturing
  - B. Discuss the changes (metrology related) in manufacturing today
    - 1. Interchangeable manufacture
    - 2. World trade
    - 3. High precision
- II. Discuss the Inch System of Measurement
  - A. Discuss fractional (scale) dimensions for linear measurement
  - B. Discuss decimal dimensions for linear measurement
  - C. Convert fractional to decimal
    - 1. Review mathematical conversion method
    - 2. Fractional/decimal conversion charts
  - D. Practice and demonstration of skills listed above
- III. Discuss the Metric System of Measurement
  - A. Discuss the units of measure commonly used in the metric system
  - B. Convert inch to metric
    - 1. Review mathematical method (1 inch = 25.4 mm)
    - 2. Conversion charts
  - C. Practice and demonstration of skills listed above
- IV. Discuss Semi-Precision and Precision Measurement
  - A. Discuss the difference between semi-precision and precision measurement
    - 1. Semi-precision measurements are 1/64" (.5mm) or greater
    - 2. Precision measurements are less than 1/64" (.5mm)
  - B. Discuss the five categories of precision measurement
    - 1. Outside measurement
    - 2. Inside measurement
    - 3. Depth measurement
    - 4. Thread measurement
    - 5. Height measurement
- V. Discuss the Following Measurement Terms: Accuracy, Precision, Reliability, and Discrimination

A. *Accuracy* - whether or not something is made according to standard. (The standard for manufacturing is the blueprint.)
B. *Precision* - the degree of exactness required for an application or design requirement
C. *Reliability* - the ability to consistently obtain the desired result
D. *Discrimination* - the degree that a measuring instrument divides its basic unit of length

Practical Application:

Students will understand the differences in metric and English measurements, will recognize different measuring tools, and will understand the principles of precision measurement.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-E2) dealing with the selection of the correct measuring tool based on tool characteristics and measurement requirements.

CNC-E1-HO
Understand Metrology Terms
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:
- a. Discuss the use of metrology in manufacturing;
- b. Discuss the Inch system of measurement;
- c. Discuss the Metric system of measurement;
- d. Discuss semi-precision and precision measurement; and,
- e. Discuss the following: precision, reliability, discrimination, and accuracy.

Module Outline:

- I. Discuss the Use of Metrology in Manufacturing
  - A. Discuss the function and reason for measurements in manufacturing
  - B. Discuss the changes (metrology related) in manufacturing today
    - 1. Interchangeable manufacture
    - 2. World trade
    - 3. High precision
- II. Discuss the Inch System of Measurement
  - A. Discuss fractional (scale) dimensions for linear measurement
  - B. Discuss decimal dimensions for linear measurement
  - C. Convert fractional to decimal
    - 1. Review mathematical conversion method
    - 2. Fractional/decimal conversion charts
  - D. Practice and demonstration of skills listed above
- III. Discuss the Metric System of Measurement
  - A. Discuss the units of measure commonly used in the metric system
  - B. Convert inch to metric
    - 1. Review mathematical method (1 inch = 25.4 mm)
    - 2. Conversion charts
  - C. Practice and demonstration of skills listed above
- IV. Discuss Semi-Precision and Precision Measurement
  - A. Discuss the difference between semi-precision and precision measurement
    - 1. Semi-precision measurements are 1/64" (.5mm) or greater
    - 2. Precision measurements are less than 1/64" (.5mm)
  - B. Discuss the five categories of precision measurement
    - 1. Outside measurement
    - 2. Inside measurement
    - 3. Depth measurement

        4. Thread measurement
        5. Height measurement

V. Discuss the Following Measurement Terms: Accuracy, Precision, Reliability, and Discrimination
    A. *Accuracy* - whether or not something is made according to standard. (The standard for manufacturing is the blueprint.)
    B. *Precision* - the degree of exactness required for an application or design requirement
    C. *Reliability* - the ability to consistently obtain the desired result
    D. *Discrimination* - the degree that a measuring instrument divides its basic unit of length

Name__________________________ Date_______________

CNC-E1
Understand Metrology Terms
Self-Assessment

Circle the letter preceding the correct answer.

1. Which of the following is not a term for the science of measuring?
    A. Calibration
    B. Comparison
    C. Measurology
    D. Metrology

2. Name two systems of measurement presently used in the United States.
    A. Fractions and decimals
    B. Metric and inch
    C. Precision and non-precision
    D. Inside and outside

3. What is the most common inch to metric conversion factor in use today?
    A. 1" = 25.4mm
    B. 1mm = .25.4"
    C. 1' = 12mm
    D. 1/16" = 64mm

4. Precision measurement can be defined as any measurement made to a degree finer than:
    A. 1/8".
    B. 1/16".
    C. 1/32".
    D. 1/64".

5. Precision measurement can also be defined as any measurement made to a degree finer than:
    A. .25mm.
    B. .5mm.
    C. .10mm.
    D. 3.24mm.

6. ______________ in metrology refers to whether or not a specific measurement is actually within its stated size.
A. Precision
B. Reliability
C. Discrimination
D. Accuracy

7. ______________ in metrology is relative to the specific measurement being made, with regard to the degree of exactness required.
A. Precision
B. Reliability
C. Discrimination
D. Accuracy

8. ______________ in metrology refers to the degree to which a measuring instrument divides the basic unit of length it is using for measurement.
A. Precision
B. Reliability
C. Discrimination
D. Accuracy

9. ______________ in metrology refers to the ability to obtain the desired result to the degree of precision required.
A. Precision
B. Reliability
C. Discrimination
D. Accuracy

10. The five categories of precision measurement are outside, inside, length, depth, and:
A. Taper
B. Rpm
C. Thread
D. Rms

CNC-E1
Understand Metrology Terms
Self-Assessment Answer Key

1.	B
2.	B
3.	A
4.	D
5.	B
6.	D
7.	A
8.	C
9.	B
10.	C

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-E2

Subject: **Advanced CNC and CAM** **Time: 4 Hrs.**

Duty: **Measure/Inspect**
Task: Select Measurement Tools

Objective(s):

Upon completion of this unit the student will be able to:
a. Identify basic semi-precision measuring tools;
b. Identify precision measuring tools;
c. Justify use of particular measurement tools based on tool characteristics;
d. Identify error possibilities in measurement tool selection; and,
e. Demonstrate proper care of precision measuring tools.

Instructional Materials:

MASTER Handout (CNC-E2-HO)
MASTER Laboratory Aid (CNC-E2-LA)
MASTER Self-Assessment
Steel Rules (metric and fractional)
0-1" micrometer
Assortment of outside (larger than 1") micrometers
1 set inside micrometers
1 depth micrometer set
1 ea. - outside spring caliper and inside spring caliper
6" dial calipers
1 ea. - Digital micrometer and digital vernier caliper
1 ea. - Set of telescoping gages and set of small hole gages
Examples of "go/no-go" gages

References:

Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition, "Dimensional Measurement"
NTMA Modules:

MA-I-05	"Steel Rules"
MA-I-09	"Steel Rules and Transfer Tools"
MA-I-13	"Micrometers"
MA-I-17	"Vernier Instruments

Student Preparation:

Students should have previously completed the following **MASTER** Technical Modules:

CNC-E1 "Understand Metrology Terms"

Introduction:

A person choosing to enter the machinist trade is often surprised at the number of measuring tools available to such workers. With hundreds of these tools to choose from, the machinist has a tool to cover almost any conceivable measuring situation. Often these tools are used alone or in combination with other measuring tools. As you begin your machinist career, it is important that you learn to properly identify, use and care for these precision instruments.

Presentation Outline:

I. Describe and Discuss the Following Semi-Precision Measuring Tools
   A. Steel rules
   B. Calipers
   C. Squares
II. Describe and Discuss the Following Precision Measuring Tools
   A. Micrometers (outside, inside and depth)
   B. Verniers (calipers and height gage)
   C. Gages (small hole, telescope, fixed, and dial bore)
III. Justify Use of Particular Measurement Tools Based on Tool Characteristics
   A. What tolerance is required by the print?
   B. What physical characteristics of the part influence tool selection?
   C. What is the discrimination of the tool?
   D. How much time is available for part measurement/inspection?
   E. Will the tool be used by itself or in conjunction with some other tool?
   F. What is the most reliable tool for this application?
IV. Identify Error Possibilities in Measurement Tool Selection
   A. Part not being produced to specifications
   B. Too much time spent trying to measure correctly by not having the right tool
V. Demonstrate Proper Care of Precision Measuring Tools
   A. Storage
   B. Handling
   C. Cleaning

Practical Application:

Complete the Self-Assessment at the end of the chapters in the text.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-E3) dealing with measuring with hand held machinist measuring instruments.

CNC-E2-HO
Select Measurement Tools
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Identify basic semi-precision measuring tools;
b. Identify precision measuring tools;
c. Justify use of particular measurement tools based on tool characteristics;
d. Identify error possibilities in measurement tool selection; and,
e. Demonstrate proper care of precision measuring tools.

Module Outline:

I. Describe and Discuss the Following Semi-Precision Measuring Tools
    A. Steel rules
    B. Calipers
    C. Squares
II. Describe and Discuss the Following Precision Measuring Tools
    A. Micrometers (outside, inside and depth)
    B. Verniers (calipers and height gage)
    C. Gages (small hole, telescope, fixed, and dial bore)
III. Justify Use of Particular Measurement Tools Based on Tool Characteristics
    A. What tolerance is required by the print?
    B. What physical characteristics of the part influence tool selection?
    C. What is the discrimination of the tool?
    D. How much time is available for part measurement/inspection?
    E. Will the tool be used by itself or in conjunction with some other tool?
    F. What is the most reliable tool for this application?
IV. Identify Error Possibilities in Measurement Tool Selection
    A. Part not being produced to specifications
    B. Too much time spent trying to measure correctly by not having the right tool
V. Demonstrate Proper Care of Precision Measuring Tools
    A. Storage
    B. Handling
    C. Cleaning

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

Name__________________________ Date_______________

CNC-E2
Select Measurement Tools
Self-Assessment

Circle the letter preceding the best answer.

1. A ______________ is a linear measuring instrument whose graduations represent real units of length .
   - A. Steel tape
   - B. Scale
   - C. Rule
   - D. Yardstick

2. A vernier caliper has two scales: the vernier scale and the________________.
   - A. Top scale
   - B. Main scale
   - C. Principle scale
   - D. Inside scale

3. What is the discrimination for vernier instruments used for linear measurement?
   - A. .001"
   - B. .02mm
   - C. 1/64"
   - D. A and B above

4. How are metric scales usually graduated?
   - A. Meters
   - B. Feet and inches
   - C. Milliliters
   - D. MM and .5mm

5. The machinist combination set incudes 4 components: the steel rule, the protractor head, the square head, and ______________ .
   - A. Magnetic base
   - B. Protective cover
   - C. Center head
   - D. Adjustable depth gage

6. The vernier caliper may be used for inside measurement, outside measurement and _______________ .
   A. Diameter measurement
   B. Length measurement
   C. Depth measurement
   D. All of the above

7. Which of the following is not a valid type of micrometer?
   A. Outside micrometer
   B. Universal micrometer
   C. Thread micrometer
   D. Digital micrometer

8. Which of the following does the most harm to precision measuring tools?
   A. Heat
   B. Dirt
   C. Moisture
   D. Oil

9. A standard micrometer has a discrimination of what part of an inch?
   A. .0001"
   B. .001"
   C. .010"
   D. .100"

10. In order to be certain of the dimension when measuring with a micrometer: _______________ .
   A. Take at least one reading
   B. Take at least two readings
   C. Take at least three readings
   D. Take at least four readings

CNC-E2
Select Measurement Tools
Self-Assessment Answer Key

1. C
2. B
3. D
4. D
5. C
6. D
7. B
8. C
9. B
10. B

MACHINIST SERIES

MASTER Technical Module No. CNC-E3

Subject: **Conventional Machining** **Time: 4 Hrs.**

Duty: **Measure/Inspect**
Task: Measure with Hand Held Instruments

Objective(s):

Upon completion of this unit the student will be able to:

a. Measure with steel rules (metric and inch);
b. Measure with micrometers;
c. Measure with comparison measuring instruments (e.g., calipers, telescope gages);
d. Measure with direct measuring instruments (e.g., vernier, dial and digital instruments); and,
e. Measure with fixed gages (go and no-go gages).

Instructional Materials:

MASTER Handout (CNC-E3-HO)
MASTER Laboratory Exercise (CNC-E3-LE1)
MASTER Laboratory Exercise (CNC-E3-LE2)
MASTER Laboratory Aid (CNC-E3-LA)
Steel Rules (metric and fractional) for each student or group of students
0-1" micrometers for each student or group of students
Assortment of outside (larger than 1") micrometers
1 set inside micrometers
1 depth micrometer set
1 ea. - outside spring caliper and inside spring caliper
6" dial calipers for each student or group of students
Random collection of objects for student practice
1 ea. - Digital micrometer and digital vernier caliper
1 ea. - Set of telescoping gages and set of small hole gages
Examples of "go/no-go" gages

References:

Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition, "Dimensional Measurement"
NTMA Modules:
MA-I-05 "Steel Rules"

MA-I-09	"Steel Rules and Transfer Tools"
MA-I-13	"Micrometers"
MA-I-17	"Vernier Instruments"

Student Preparation:

Students should have previously completed the following MASTER Technical Modules:

CNC-E1	"Understand Metrology Terms"
CNC-E2	"Select Measurement Tools"

Introduction:

Every aspect of our lives, from the clothes we wear to the cars we drive, is greatly influenced by measurement. For the machinist, measurement is especially important since it is the machinist who is responsible for crafting the tools, fixtures, and components which make up or support virtually every part of our lives. Therefore, it is essential for the machinist to be a master in the use of not only the machine tools, but also the instruments which are used to measure the precision components demanded by consumers today. One of the most valuable assets you can possess is the expert use of the machinist measuring tools and a desire to practice quality consciousness in every aspect of your job performance.

Presentation Outline:

I. Discuss the Importance of Learning and Practicing Proper Measurement Techniques
   A. Show the video "Measuring Tools"
   B. Give each student a copy of the handout "Proper Measuring Techniques"
II. Discuss and Demonstrate Proper Measurement Techniques Using the Steel Rule
III. Discuss and Demonstrate the Use of Micrometer Type Measuring Instruments
   A. Outside micrometers
   B. Inside micrometers
   C. Depth micrometers
   D. Practice and demonstration of skills listed above
IV. Discuss and Demonstrate the Use of Transfer Type Measuring Instruments
   A. Spring calipers (inside and outside)
   B. Telescope gages
   C. Small hole gages
   D. Practice and demonstration of skills listed above
V. Discuss and Demonstrate the Use of Direct Measuring Instruments

A. Vernier calipers
B. Dial calipers
C. Digital calipers
D. Practice and demonstration of skills listed above

VI. Discuss the Purpose of Fixed Gages and Demonstrate Their Use
A. Cylindrical plug and ring gages
B. Taper plug and ring gages
C. Snap gages
D. Thread plug gages
E. Practice and demonstration of skills listed above

VII. Complete Practical Exercises (CNC-E3-LE1) and (CNC-E3-LE2) On All the Above Material

Practical Application:

Students will practice in the lab with each measuring instrument and complete the Laboratory Worksheet (CNC-E3-LW) and turn it in to the instructor for evaluation.

Evaluation and/or Verification:

Given: All the measuring instruments listed in the "Instructional Materials" and appropriate sample workpieces to measure;

The student will: Study the material as presented by the instructor, evaluate his/her skills through the Self-Assessment, and demonstrate those skills through the Laboratory Worksheet.

The standards of skill performance are that the student will:

1. Score 90% on the Self-Assessment;
2. Measure with the steel rule to an accuracy of ±1/64 inch;
3. Measure with the micrometer to an accuracy of ±0.001 inch;
4. Measure with the dial and digital caliper to an accuracy of ±0.001 inch; and,
5. Determine whether the holes, tapers, and threads are within acceptable limits by use of the appropriate go/no-go gages.

Summary:

Review the main lesson points. Hold class discussion and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-E4) dealing with eliminating variables which affect accurate measurement.

CNC-E3-HO
Measure With Hand Held Instruments
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Measure with steel rules (metric and inch);
b. Measure with micrometers;
c. Measure with comparison measuring instruments (e.g., calipers, telescope gages);
d. Measure with direct measuring instruments (e.g., vernier, dial and digital instruments); and,
e. Measure with fixed gages (go and no-go gages).

Module Outline:

I. Discuss the Importance of Learning and Practicing Proper Measurement Techniques
    A. Show the video "Measuring Tools"
    B. Give each student a copy of the handout "Proper Measuring Techniques"
II. Discuss and Demonstrate Proper Measurement Techniques Using the Steel Rule
III. Discuss and Demonstrate the Use of Micrometer Type Measuring Instruments
    A. Outside micrometers
    B. Inside micrometers
    C. Depth micrometers
    D. Practice and demonstration of skills listed above
IV. Discuss and Demonstrate the Use of Transfer Type Measuring Instruments
    A. Spring calipers (inside and outside)
    B. Telescope gages
    C. Small hole gages
    D. Practice and demonstration of skills listed above
V. Discuss and Demonstrate the Use of Direct Measuring Instruments
    A. Vernier calipers
    B. Dial calipers
    C. Digital calipers
    D. Practice and demonstration of skills listed above
VI. Discuss the Purpose of Fixed Gages and Demonstrate Their Use
    A. Cylindrical plug and ring gages
    B. Taper plug and ring gages
    C. Snap gages
    D. Thread plug gages
    E. Practice and demonstration of skills listed above

VII. Complete Practical Exercise (CNC-E3-LE1) and (CNC-E3-LE2) On All the Above Material

Name:__________________ Date:________________________

CNC-E3-LE1
Measure With Hand Held Instruments
Attachment 2: MASTER Laboratory Exercise No. 1

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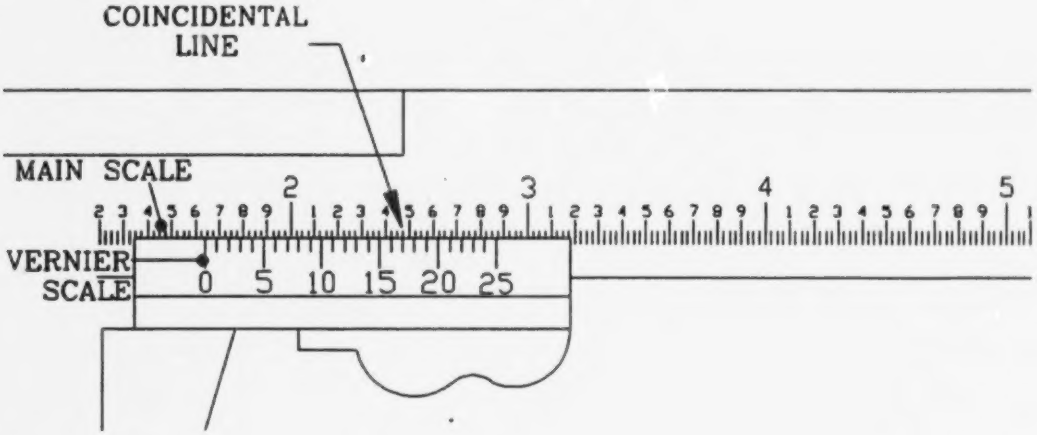
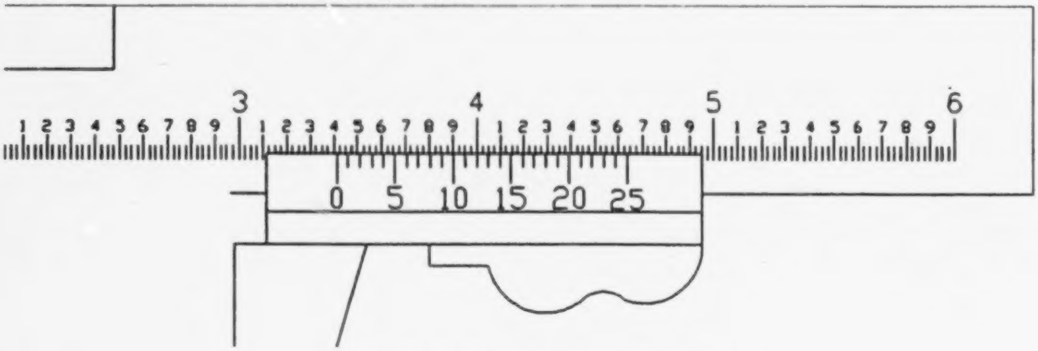
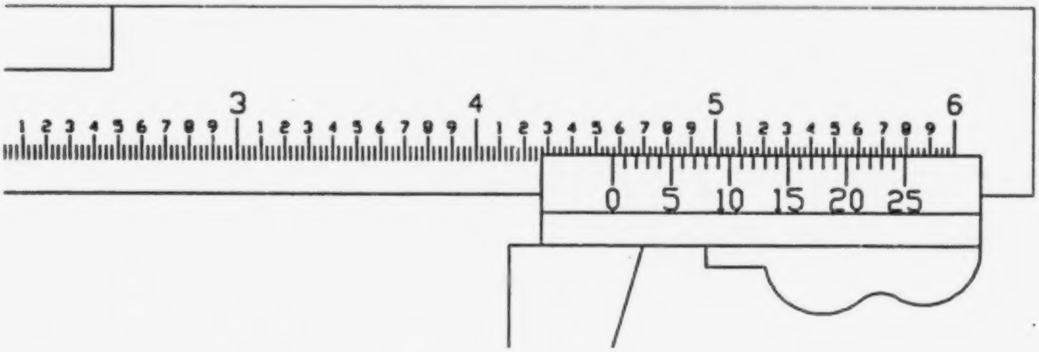
1. What is the reading on the vernier caliper below?
   - a. .642
   - b. 1.642
   - c. 1.645
   - d. 1.64


COINCIDENTAL LINE
MAIN SCALE
VERNIER SCALE
2
3
4
5
1 2 3 4 5 6 7 8 9
0
5
10
15
20
25

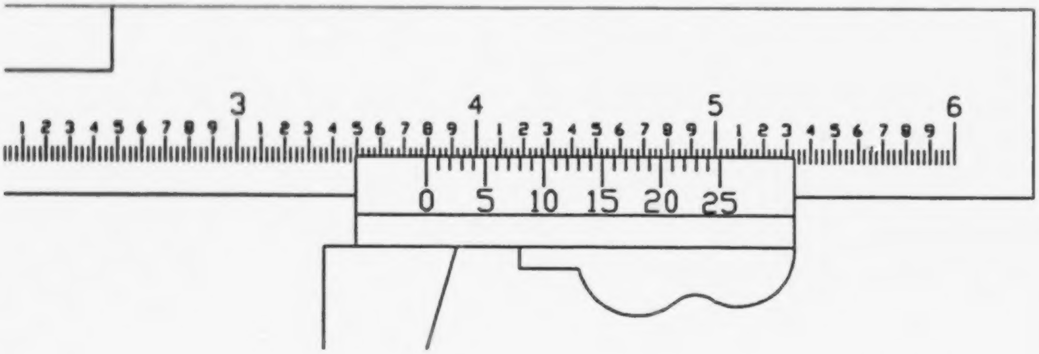
2. What is the reading on the vernier caliper below?
   - a. .415
   - b. 3.125
   - c. 3.405
   - d. 3.412


3
4
5
6
1 2 3 4 5 6 7 8 9
0
5
10
15
20
25

3. What is the reading on the vernier caliper below?
   a. 4.575
   b. 4.250
   c. 4.570
   d. 4.275


3
4
5
6
1 2 3 4 5 6 7 8 9
0 5 10 15 20 25

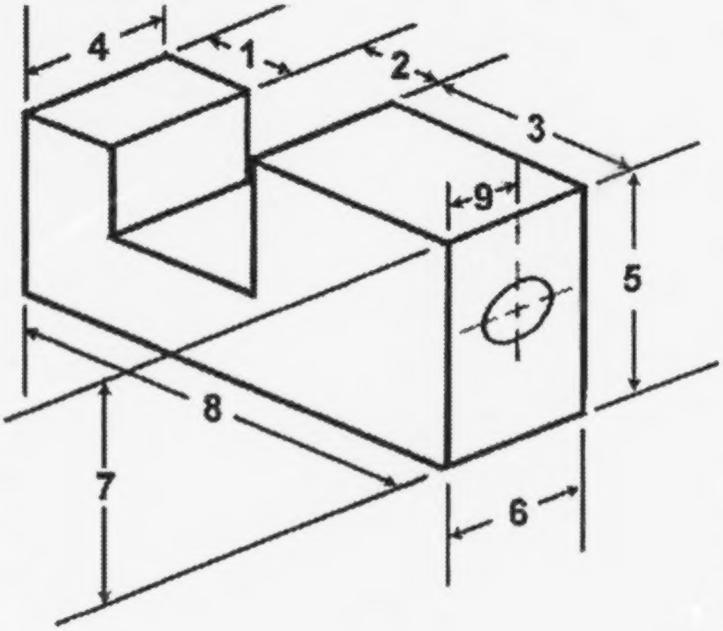
4. What is the reading on this vernier caliper?
   a. 3.785
   b. 3.800
   c. 3.473
   d. 3.793


3
4
5
6
1 2 3 4 5 6 7 8 9
0 5 10 15 20 25

Name_________________________ Date______________

CNC-E3-LE2
Measure With Hand Held Instruments
Attachment 3: MASTER Laboratory Exercise No. 2

Using the measuring instruments provided for you and the measuring specimens, measure for the following dimensions and record your answers in the space provided. Be sure to provide metric and inch answers for each dimension. Turn this sheet in to your instructor for evaluation.



Specimen Number _______

Dimension	metric	inch	Dimension	metric	inch
1.	_____	_____	7.	_____	_____
2.	_____	_____	8.	_____	_____
3.	_____	_____	9.	_____	_____
4.	_____	_____	10.	_____	_____
5.	_____	_____	11.	_____	_____
6.	_____	_____			

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-E4

Subject: **Advanced CNC and CAM** **Time: 4 Hrs.**

Duty: **Measure/Inspect**
Task: Eliminate Measurement Variables

Objective(s):

Upon completion of this unit the student will be able to:
a. Discuss factors affecting accurate measurement (dirt, temperature, improper measuring tool calibration);
b. Explain calibration requirements of various precision instruments;
c. Illustrate measurement differences when taken with calibrated and non-calibrated instruments; and,
d. Calibrate a micrometer type measuring tool.

Instructional Materials:

MASTER Handout (CNC-E4-HO)
MASTER Laboratory Exercise (CNC-E4-LE)
MASTER Laboratory Aid (CNC-E4-LA)
MASTER Self-Assessment
Assortment of outside micrometers with standards and adjusting wrench
Dial calipers with adjustment tool
Set of gage blocks

References:

Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition, "Dimensional Measurement"

Student Preparation:

Students should have previously completed the following **MASTER** Technical Modules:
CNC-E1 "Understand Metrology Terms"
CNC-E2 "Select Measurement Tools"
CNC-E3 "Measure With Hand Held Instruments"

Introduction:

Simply possessing the finest measuring tools that money can buy does not insure precision measurement. Many other factors affect accurate measurement. The machinist must learn how to prepare the surface for measurement, how to manipulate the measuring tools correctly, and how to check the calibration of those measuring tools. All of these things are important if the machinist is to consistently make accurate measurements.

Presentation Outline:

I. Discuss Factors Affecting Accurate Measurement
  A. Tool selection
  B. Cleanliness
  C. Temperature
  D. Calibration
  E. "Feel"
II. Explain Calibration Requirements of Various Precision Instruments
  A. Individual responsibility vs. company responsibility
  B. Calibration standards
III. Illustrate Measurement Differences When Taken With Calibrated and Non-Calibrated Instruments
IV. Calibrate a Micrometer Type Measuring Tool
  A. 5 steps adjusting an outside micrometer which needs adjustment
    1. Clean the measuring faces of the micrometer
    2. Close the measuring faces carefully against the standard by turning the ratchet stop or friction thimble
    3. Insert the C-spanner into the hole or slot provided in the sleeve
    4. Carefully turn the sleeve until the index line on the sleeve coincides with the zero line on the thimble
    5. Recheck the accuracy of the micrometer by opening and then closing the micrometer faces by turning the ratchet stop or friction thimble
  B. Student practice of the above procedure

Practical Application:

Students will clean, check and calibrate an outside micrometer.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-E5) on the subject of performing measurements and inspections using a surface plate and accessories

CNC-E4-HO
Eliminate Measurement Variables
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

- a. Discuss factors affecting accurate measurement (dirt, temperature, improper measuring tool calibration);
- b. Explain calibration requirements of various precision instruments;
- c. Illustrate measurement differences when taken with calibrated and non-calibrated instruments; and,
- d. Calibrate a micrometer type measuring tool.

Module Outline:

- I. Discuss Factors Affecting Accurate Measurement
  - A. Tool selection
  - B. Cleanliness
  - C. Temperature
  - D. Calibration
  - E. "Feel"
- II. Explain Calibration Requirements of Various Precision Instruments
  - A. Individual responsibility vs. company responsibility
  - B. Calibration standards
- III. Illustrate Measurement Differences When Taken With Calibrated and Non-Calibrated Instruments
- IV. Calibrate a Micrometer Type Measuring Tool
  - A. 5 steps adjusting an outside micrometer which needs adjustment
    - 1. Clean the measuring faces of the micrometer
    - 2. Close the measuring faces carefully against the standard by turning the ratchet stop or friction thimble
    - 3. Insert the C-spanner into the hole or slot provided in the sleeve
    - 4. Carefully turn the sleeve until the index line on the sleeve coincides with the zero line on the thimble
    - 5. Recheck the accuracy of the micrometer by opening and then closing the micrometer faces by turning the ratchet stop or friction thimble
  - B. Student practice of the above procedure

CNC-E4-LE
Eliminate Measurement Variables
Attachment 2: MASTER Laboratory Exercise

The student will perform the following:

1. **Calibrate a micrometer by:**
   a. **Adjusting micrometer;**
   b. **Cleaning the measuring faces of the micrometer;**
   c. **Closing the measuring faces carefully against the standard by turning the ratchet stop or friction thimble;**
   d. **Inserting the C-spanner into the hole or slot provided in the sleeve;**
   e. **Carefully turning the sleeve until the index line on the sleeve coincides with the zero line on the thimble; and,**
   f. **Rechecking the accuracy of the micrometer by opening and then closing the micrometer faces by turning the ratchet stop or friction thimble.**

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

Name______________________________ Date________________

CNC-E4
Eliminate Measurement Variables
Self-Assessment

Write the answers to the following questions in the space provided.

1. List 5 factors which may affect accurate measurement.

2. Briefly explain why some companies place the burden of calibration on the machinist while other companies employ persons to calibrate the tools and instruments of the machinist.

3. Even though standards are furnished with many outside micrometers, what is generally considered to the best standard to use for calibration of machinist measuring instruments?

4. **Why are many inspection/quality control stations located in climate controlled areas?**

____

____

____

5. **List the steps (in order) to follow should the accuracy of a micrometer require adjustment.**

1. ______________________________

   ____

2. ______________________________

   ____

3. ______________________________

   ____

4. ______________________________

   ____

5. ______________________________

   ____

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-E5

Subject: **Advanced CNC and CAM** **Time: 8 Hrs.**

Duty: **Measure/Inspect**
Task: Measure/Inspect Using Surface Plate and Accessories

Objective(s):

Upon completion of this unit the student will be able to:
a. Describe care of surface plate;
b. Use surface plate accessories correctly (sine bar, gage blocks, etc.);
c. Check for part squareness;
d. Check part dimensions for accuracy; and,
e. Align workpieces using height gage and dial indicators.

Instructional Materials:

MASTER Handout (CNC-E5-HO)
MASTER Laboratory Exercise (CNC-E5-LE)
MASTER Laboratory Aid (CNC-E5-LA)
MASTER Self-Assessment
Surface plate and accessories
Parts to check

References:

Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition, "Layout"

Student Preparation:

Students should have previously completed the following **MASTER** Technical Modules:

CNC-E1	"Understand Metrology Terms"
CNC-E2	"Select Measurement Tools"
CNC-E3	"Measure With Hand Held Instruments"
CNC-E4	"Eliminate Measurement Variables"

Introduction:

Much of the measuring that a machinist performs is done at various points during the processing of the workpiece. Whenever a higher degree of precision is required or whenever the work has been removed from the machine, the work is often subjected to inspection. This inspection process is frequently accomplished on a surface plate using a set of accessories which are specifically for use with the surface plate. This lesson will cover the use of the surface plate and the accessories which are used for layout and inspection purposes.

Presentation Outline:

I. Describe Types of Surface Plate and Surface Tables
  A. Cast iron and semi-steel surface plates
  B. Granite surface plate
II. Discuss the Different Surface Plate Accessories and Their Use
  A. Sine bar
  B. Gage blocks
  C. Vernier height gage
  D. Precision height gage
  E. Dial test indicator
  F. Squares
  G. Angle plate and clamps
  H. 1,2,3 blocks
III. Demonstrate Checking For Part Squareness
IV. Demonstrate Checking Part Dimensions For Accuracy
V. Demonstrate Aligning Workpieces Using Height Gage and Dial Indicators

Practical Application:

Students will complete assignments using a surface plate, gage blocks, sine bar, and other accessories normally used in conjunction with the surface plate.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-E6) dealing with the use of stationary equipment for inspection purposes.

CNC-E5-HO
Measure/Inspect Using Surface Plate and Accessories
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:
- a. Describe care of surface plate;
- b. Use surface plate accessories correctly (sine bar, gage blocks, etc.);
- c. Check for part squareness;
- d. Check part dimensions for accuracy; and,
- e. Align workpieces using height gage and dial indicators.

Module Outline:

I. Describe Types of Surface Plate and Surface Tables
  - A. Cast iron and semi-steel surface plates
  - B. Granite surface plate

II. Discuss the Different Surface Plate Accessories and Their Use
  - A. Sine bar
  - B. Gage blocks
  - C. Vernier height gage
  - D. Precision height gage
  - E. Dial test indicator
  - F. Squares
  - G. Angle plate and clamps
  - H. 1,2,3 blocks

III. Demonstrate Checking For Part Squareness

IV. Demonstrate Checking Part Dimensions For Accuracy

V. Demonstrate Aligning Workpieces Using Height Gage and Dial Indicators

CNC-E5-LE
Measure/Inspect Using Surface Plate and Accessories
Attachment 2: MASTER Laboratory Exercise

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1. Instructor will provide sample mechanical parts for students to:
   a. Demonstrate checking for part squareness;
   b. Demonstrate checking part dimensions for accuracy; and,
   c. Demonstrate aligning workpieces using height gage and dial indicators.

2. Students will practice:
   a. Checking for part squareness;
   b. Checking part dimensions for accuracy; and,
   c. Aligning workpieces using height gage and dial indicators.

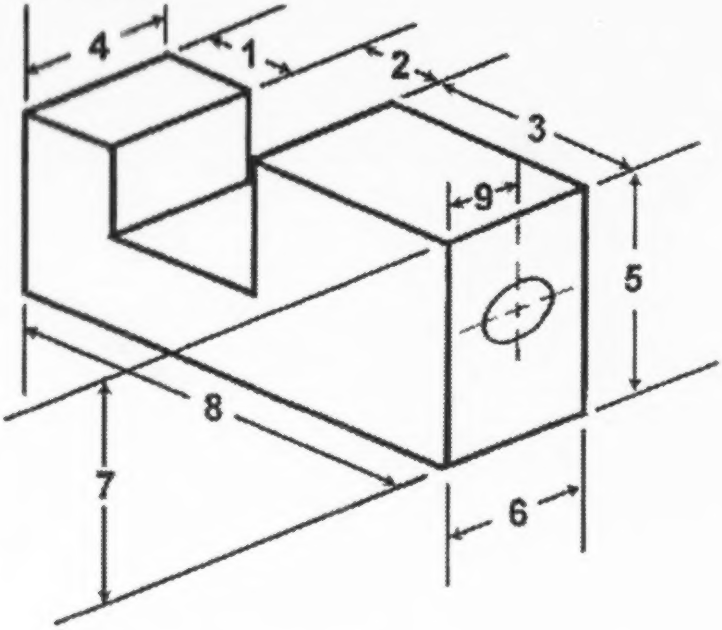
Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

Name______________________________ Date________________

CNC-E5
Measure/Inspect Using Surface Plate and Accessories
Self-Assessment

Using the measuring instruments provided for you and the measuring specimens, measure for the following dimensions and record your answers in the space provided. Be sure to provide metric and inch answers for each dimension. Turn this sheet in to your instructor for evaluation.



Dimension	metric	inch	Dimension	metric	inch
1.	_____	_____	11.	_____	_____
2.	_____	_____	12.	_____	_____
3.	_____	_____	13.	_____	_____
4.	_____	_____	14.	_____	_____
5.	_____	_____	15.	_____	_____

6. _____ _____

7. _____ _____

8. _____ _____

9. _____ _____

10. _____ _____

16. _____ _____

17. _____ _____

18. _____ _____

19. _____ _____

20. _____ _____

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-E6

Subject: **Advanced CNC and CAM** **Time: 12 Hrs.**

Duty: **Measure/Inspect**
Task: Inspect Using Stationary Equipment

Objective(s):

Upon completion of this unit the student will be able to:
a. Set up and use an Optical Comparator; and,
b. Set up and use a Coordinate Measuring Machine (CMM).

Instructional Materials:

MASTER Handout (CNC-E6-HO)
MASTER Laboratory Exercise (CNC-E6-LE)
MASTER Laboratory Aid (CNC-E6-LA)
MASTER Self-Assessment
Optical Comparator
Coordinate Measuring Machine
Samples for Measurement

References:

Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition
Instructor's Manual, Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition
Workbook for Machining Fundamentals, John R. Walker, The Goodheart-Willcox Company, Inc. Publishing, Latest Edition

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Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-E1	"Understand Metrology Terms"
CNC-E2	"Select Measurement Tools"
CNC-E3	"Measure With Hand Held Instruments"
CNC-E4	"Eliminate Measurement Variables"
CNC-E5	"Measure/Inspect Using Surface Plate and Accessories"

Introduction:

Today's manufacturing processes require much higher degrees of precision. Many components are also manufactured at one location then shipped to another for assembly. These factors have caused the machinist to rely more and more on measuring and inspecting instruments with higher degrees of precision. Free standing inspection devices such as the optical comparator and the coordinate measuring machine (CMM) are being used to help the machinist maintain the high levels of precision required by manufacturers and consumers alike.

Presentation Outline:

I. Define the Term "Comparison Measurement"
    A. Describe the following comparison instruments:
        1. Dial indicator
        2. Mechanical comparator
        3. Optical comparator
        4. Mechanical-optical comparator
        5. Air gages
        6. Electronic comparator
    B. Demonstrate the setup and operation of the optical comparator
    C. Allow students to practice setup and operation of the optical comparator
II. Discuss the Advantages of Measuring with the Coordinate Measuring Machine (CMM)
    A. Demonstrate the setup and operation of the CMM
    B. Allow students to practice setup and operation of the CMM

Practical Application:

Students will complete assignments using the optical comparator and the coordinate measuring machine.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-F1) dealing with preparing and planning for conventional machining operations.

CNC-E6-HO
Inspect Using Stationary Equipment
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Set up and use an Optical Comparator; and,
b. Set up and use a Coordinate Measuring Machine (CMM).

Module Outline:

I. Define the Term "Comparison Measurement"
  A. Describe the following comparison instruments:
    1. Dial indicator
    2. Mechanical comparator
    3. Optical comparator
    4. Mechanical-optical comparator
    5. Air gages
    6. Electronic comparator
  B. Demonstrate the setup and operation of the optical comparator
  C. Allow students to practice setup and operation of the optical comparator
II. Discuss the Advantages of Measuring with the Coordinate Measuring Machine (CMM)
  A. Demonstrate the setup and operation of the CMM
  B. Allow students to practice setup and operation of the CMM

CNC-E6-LE
Inspect Using Stationary Equipment
Attachment 2: MASTER Laboratory Exercise

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1. The instructor will:
   a. Demonstrate the setup and operation of the optical comparator; and,
   b. Demonstrate the setup and operation of the Coordinate Measuring Machine (CMM).

2. The students will:
   a. Practice the setup and operation of the optical comparator; and,
   b. Practice the setup and operation of the Coordinate Measuring Machine (CMM).

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

Name___________________________ Date_______________

CNC-E6
Inspect Using Stationary Equipment
Self-Assessment

Circle the letter preceding the best answer.

1. The CMM measures workpieces in ___ dimensions.
   A. One
   B. Two
   C. Three
   D. Four
   E. None of the above answers is correct.

2. Optical comparators project a ___ shadow of the object.
   A. Magnified
   B. True size
   C. Miniaturized
   D. Any of the above answers could be correct, depending on how the machinist sets up the comparator.
   E. None of the above answers is correct.

3. Which of the following *cannot* be checked using the optical comparator?
   A. Screw threads
   B. Gears
   C. Cutting tools
   D. All of the above are normally checked with optical comparators.
   E. None of the above answers is correct.

4. The optical comparator often uses ___ to check the workpiece.
   A. Ideal models
   B. Templates
   C. Photographs
   D. All of the above are used with the comparator.
   E. None of the above answers is correct.

5. The CMM is useful for checking ___ among parts.
   A. Relative locations
   B. Relative sizes
   C. Relative weights
   D. All of the above answers are correct.
   E. None of the above answers is correct.

CNC-E6
Inspect Using Stationary Equipment
Self-Assessment Answer Key

1. C

2. A

3. D

4. B

5. A

CNC MACHINIST .... programs, edits, sets up, and operates CNC lathes, mills and grinders to perform machining operations necessary to produce workpieces to referenced engineering standards.

Duties ← **Tasks** →

A	**Practice Safety**	A-1 Follow safety manuals and all safety regulations/ requirements	A-2 Use protective equipment	A-3 Follow safe operating procedures for hand and machine tools	A-4 Maintain a clean and safe work environment	A-5 MSDS/ control chemical hazards								
B	**Apply Mathematical Concepts**	B-1 Perform basic arithmetic functions	B-2 Convert fractions/ decimals	B-3 Convert Metric/ English measurements	B-4 Perform basic algebraic operations	B-5 Use practical geometry	B-6 Understand basic trigonometry	B-7 Calculate speeds and feeds for machining	B-8 Use coordinate systems					
C	**Interpret Engineering Drawings and Control Documents**	C-1 Identify basic layout of drawings	C-2 Identify basic types of drawings	C-3 Review blueprint notes and dimensions	C-4 List the purpose of each type of drawing	C-5 Verify drawing elements	C-6 Practice Geometric Dimensioning and Tolerancing (GD&T)	C-7 Analyze bill of materials (BOM)	C-8 Describe the relationship of engineering drawings to planning	C-9 Understand and use quality systems	C-10 Verify standard requirements			
D	**Recognize Different Manufacturing Materials and Processes**	D-1 Identify materials with desired properties	D-2 Identify materials and processes to produce a part	D-3 Describe the heat treating process	D-4 Test metal samples for hardness	D-5 Understand welding operations								
E	**Measure/ Inspect**	E-1 Understand metrology terms	E-2 Select measurement tools	E-3 Measure with hand held instruments	E-4 Eliminate measurement variables	E-5 Measure/ inspect using surface plate and accessories	E-6 Inspect using stationary equipment							
F	**Perform Conventional Machining**	F-1 Prepare and plan for machining operations	F-2 Use hand tools	F-3 Operate power saws	F-4 Operate drill presses	F-5 Operate vertical milling machines	F-6 Operate horizontal milling machines	F-7 Operate metal cutting lathes	F-8 Operate grinding/ abrasive machines					
G	**Perform Advanced Machining**	G-1 Understand CNC basics	G-2 Program CNC machines	G-3 Operate CNC machining centers (mills)	G-4 Operate CNC turning centers (lathes)									
H	**Use Verification and Communication Systems**	H-1 Use personal computer	H-2 Use various operating systems	H-3 Use computer communications systems	H-4 Use verification systems	H-5 Use the Internet								
I	**Program Using CAM System**	I-1 Understand CAD/ CAM programs	I-2 Manipulate CAD functions	I-3 Process simple tool-path data	I-4 Create advanced surface models	I-5 Process complex tool-path functions								

CNC [illegible]
[illegible]

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-F1

Subject: **Advanced CNC and CAM** **Time: 4 Hrs.**

Duty: **Perform Conventional Machining**
Task: Prepare and Plan For Machining Operations

Objective(s):

Upon completion of this unit the student will be able to:

a. Read and interpret blueprints;
b. Understand machinability and chip formation;
c. Use the *Machinery's Handbook* as a reference for machine applications;
d. Describe the tools and toolholders will be needed for machining operations;
e. Calculate speeds, feeds, and depth of cut for various machine operations;
f. Use carbides and other tool materials;
g. Assemble work holding (fixturing) components; and,
h. Perform basic semi-precision and precision layout as necessary.

Instructional Materials:

MASTER Handout (CNC-F1-HO)
MASTER Laboratory Aid (CNC-F1-LA)
MASTER Self-Assessment
Blueprints
Tools & tool materials
Fixturing components
Lay-out equipment

References:

Machinery's Handbook, Industrial Press, Latest Edition
NTMA Modules:

MA-I-03	"Blueprint Reading, Introduction"
MA-I-04	"Relative Motions Between Tool & Workpiece: Chip Formation"
MA-I-22	"Milling Machine: Speeds & Feeds/Problems"
MA-I-24	"Milling Machine: Cutters and Operations"
MA-I-32	"Engine Lathe: Cutting Tools & Fluids"

MA-I-34 “Engine Lathe: Accessories & Work Holding Devices”
MA-III-45, -49, -53, -57, -61, 65, -69, -73, -75, -77, and -79
MA-III-44, -48, -52, -56, -60, -64, and -68
“Carbide Tooling: *Assorted Topics*”

Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-A1 through CNC-A5	“Practice Safety”
CNC-B1 through CNC-B8	“Apply Mathematical Concepts”
CNC-C1 through CNC-C10	“Interpret Engineering Drawings and Control Documents”
CNC-D1 through CNC-D5	“Recognize Different Manufacturing Materials and Processes”
CNC-E1 through CNC-E6	“Measure/Inspect”

Introduction:

Before any experienced machinist begins work on a machining job, he or she will take time to plan their work so that it can be performed in the most efficient manner. Time spent in the planning of the work and the preparation of the machine and/or tools and accessories will yield increased production, better quality parts, less scrap/re-work, and more time to concentrate on better surface finishes and tighter tolerances. Incidently, all of these things are things which are highly desirable and most rewarded by employers.

Presentation Outline:

I. Plan for Machining Operation
  A. Read and interpret blueprints
  B. Understand machinability and chip formation
  C. Use the *Machinery's Handbook* as a reference for machine applications
  D. Answer the following questions
    1. What operations are necessary to produce the part? (qualify, rough, finish, grind, face, turn, thread, groove, etc.)
    2. What sequence of tools will be used?
    3. How will the part be fixtured? Fasteners should not interfere with machine moves. (Clamps, vise, chucks, collets, etc.)
    4. How many set-ups will be required?
    5. What is the accuracy required for machining dimensions?

II. Prepare for Machining Operations
  A. What type of tools and toolholders will be needed for roughing, finishing, etc.? Use carbides and other tool materials when available. Verify tool availability.

B. Calculate speeds, feeds, and depth of cut for various machine operations
C. Assemble work holding (fixturing) components
D. Perform basic semi-precision and precision layout as necessary
E. Load the part into the workholding (fixturing) device

Practical Application:

Given a blueprint, the student will design a process plan for fabricating the parts.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-F2) dealing with the selection and use of hand tools.

CNC-F1-HO
Prepare and Plan for Machining Operations
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Read and interpret blueprints;
b. Understand machinability and chip formation;
c. Use the *Machinery' s Handbook* as a reference for machine applications;
d. Describe the tools and toolholders will be needed for machining operations;
e. Calculate speeds, feeds, and depth of cut for various machine operations;
f. Use carbides and other tool materials;
g. Assemble work holding (fixturing) components; and,
h. Perform basic semi-precision and precision layout as necessary.

Module Outline:

I. Plan for Machining Operation
    A. Read and interpret blueprints
    B. Understand machinability and chip formation
    C. Use the *Machinery's Handbook* as a reference for machine applications
    D. Answer the following questions
        1. What operations are necessary to produce the part? (qualify, rough, finish, grind, face, turn, thread, groove, etc.)
        2. What sequence of tools will be used?
        3. How will the part be fixtured? Fasteners should not interfere with machine moves. (Clamps, vise, chucks, collets, etc.)
        4. How many set-ups will be required?
        5. What is the accuracy required for machining dimensions?

II. Prepare for Machining Operations
    A. What type of tools and toolholders will be needed for roughing, finishing, etc.? Use carbides and other tool materials when available. Verify tool availability.
    B. Calculate speeds, feeds, and depth of cut for various machine operations
    C. Assemble work holding (fixturing) components
    D. Perform basic semi-precision and precision layout as necessary
    E. Load the part into the workholding (fixturing) device

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
   a. No loose clothing, including ties;
   b. Long hair properly stowed;
   c. No jewelry;
   d. Hard, closed-toe shoes;
   e. Eye protection (safety glasses); and,
   f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

Name________________________ Date______________

CNC-F1
Prepare and Plan For Machining Operations
Self-Assessment

Circle the letter preceding the correct answer.

1. The intentional difference in the sizes of mating parts is called ______________ .
   A. Fit
   B. Tolerance
   C. Allowance
   D. Limits

2. The permissible variation of the size of a part is called ______________ .
   A. Fit
   B. Tolerance
   C. Allowance
   D. Limits

3. The largest and smallest permissible dimensions of a part are the ______________ .
   A. Fit
   B. Tolerance
   C. Allowance
   D. Limits

4. Which property of metals is directly related to machinability?
   A. Ductility
   B. Malleability
   C. Hardness
   D. Elasticity

5. Which of the following types of information can not be found in the *Machinery's Handbook*?
   A. Recommended cutting speeds
   B. Recommended feeds
   C. Table of composition of steels
   D. Table of machine tool builders

6. The RPM for machining a 1" diameter aluminum workpiece (SFM=500) is______________ .
   A. 1000 RPM
   B. 2000 RPM
   C. 3000 RPM
   D. 4000 RPM

7. Using the ASA system of identifying carbide inserts, an insert with the number of TNMG-323E; what does the "T" indicate?
   A. Thickness
   B. Toughness
   C. The shape
   D. Two sided

8. Which type of inserts are best suited for machining extremely hard workpieces?
   A. Carbide
   B. Cemented oxide (ceramic)
   C. Cubic boron nitride
   D. Diamond

9. The _______________ may be used to measure or mark off vertical distances.
   A. Surface gage
   B. Vernier height gage
   C. Steel rule
   D. Craftsman's vertical scribe

10. Which of the following is usually used to lay out arcs and circles?
    A. Circle template
    B. Radius gages
    C. Sine bar
    D. Dividers

CNC-F1
Prepare and Plan for Machining Operations
Self-Assessment Answer Key

1. C
2. B
3. D
4. C
5. D
6. B
7. C
8. D
9. B
10. D

ADVANCED CNC and CAM SERIES
MASTER Technical Module No. CNC-F2

Subject: Advanced CNC and CAM **Time:** 12 Hrs.

Duty: Perform Conventional Machining
Task: Use Hand Tools

Objective(s):

Upon completion of this unit the student will be able to:

a. Select and use hand tools;
b. Select and use hand files;
c. Correctly identify and use hand taps and dies as required;
d. Select and use hand reamers;
e. Use arbor and shop presses; and,
f. Perform off-hand grinding operations.

Instructional Materials:

MASTER Handout (CNC-F2-HO)
MASTER Laboratory Exercise (CNC-F2-LE)
MASTER Laboratory Aid (CNC-F2-LA)
MASTER Self-Assessment
Each student should have access to any of the hand tools which will be covered during this module.
Each student will also need to have some type of workbench with a bench vise securely mounted to the it.

References:

Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition, "Hand Tools"
Workbook for Machining Fundamentals, From Basic to Advanced Techniques, John R. Walker, The Goodheart-Willcox Co., Inc., Publishers, Latest Edition
NTMA Modules:
  MA-I-33 "Noncutting Handtools"
  MA-I-35 "Cutting Handtools"

Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-F1 "Prepare and Plan For Machining Operations"

Introduction:

One of the most important aspects of the machinist trade involves the use of hand tool operations or bench work. This may refer to operations such as laying out, fitting, and assembling. The machinist is often expected to saw, file, polish, ream, and thread using only hand tools. So the ability to select and properly use hand tools is very important and require continued practice by the machinist to master these skills.

Presentation Outline:

I. Select and Use Hand Tools
  A. Bench vise
  B. Clamps
  C. Pliers
  D. Hammers
  E. Wrenches
  F. Screwdrivers
  G. Chisels and punches
  H. Hacksaws
II. Select and Use Hand Files
  A. Types of files
    1. Mill file
    2. Long angle (lathe) file
    3. Bastard files
  B. Shapes of files
    1. Pillar files
    2. Square files
    3. Warding files
    4. Knife files
    5. Three-square files
    6. Half-found files
    7. Round files
  C. Specialty files
    1. Swiss pattern files
    2. Die sinker's rifflers
    3. Curved tooth files
    4. Thread files
    5. Rotary files and burrs
    6. Scrapers
  D. Care and use of files
    1. Proper care of files
    2. Proper use of files

a. Cross filing
b. Draw filing
E. Student filing practice
III. Correctly Identify and Use Hand Taps and Dies as Required
A. Identification of taps
1. Identifying marks on inch taps (example: ½-13-UNC)
a. Nominal size = ½"
b. Threads per inch = 13
c. Standardized thread series = Unified National Coarse
2. Identifying marks on metric taps (example: M4 X 0.7)
a. M = metric thread
b. Nominal diameter of the thread = 4mm
c. Pitch of the thread = 0.7mm
3. Standard taps
a. Taper (starting) taps
b. Plug taps
c. Taper taps
4. Special taps
a. Pipe taps
b. Pulley taps
c. Acme thread taps
B. Care and use of taps
1. Proper care of hand taps
2. Determining tap drill size
a. Tap drill size chart
b. Tap drill size formula for inch taps
Tap Drill Size = Major Diameter of the Tap minus 1 divided by the number of threads per inch
c. Tap drill size formula for metric taps
Tap Drill Size = major diameter (mm) minus the pitch (mm)
3. Demonstrate proper use of hand taps
4. Broken tap removal
a. Tap extractor
b. Acid
c. Electrical discharge
C. Identification and use of threading dies
1. Solid die - for chasing or recutting damaged threads
2. Adjustable split die - for cutting threads over or under the standard depth of thread
3. Adjustable screw plate die - most efficient type of adjustable die for cutting external threads
D. Student tap and die practice
IV. Select and Use Hand Reamers

A. Types of hand reamers
  1. Straight fluted reamers
  2. Spiral fluted reamers
  3. Expansion reamers
  4. Adjustable hand reamers
  5. Taper reamers
B. Care and Use of Hand Reamers
  1. Proper care of hand reamers
  2. Proper use of hand reamers
C. Student hand reaming practice

V. Perform Finishing Processes
  A. Broaching
  B. Lapping
  C. Polishing

VI. Use Arbor and Shop Presses
  A. To install bushings/bearings
  B. To press shafts in and out of gears and sprockets
  C. To seat mandrels
  D. To broach keyways
  E. To bend and straighten

VII. Perform Off-Hand Grinding Operations
  A. Setting up the grinder (demonstration)
    1. Grinding wheel selection
    2. Grinding wheel "ring test"
    3. Mounting the grinding wheel
    4. Tool rest adjustment
    5. Dressing the grinding wheel
  B. Perform off-hand grinding exercises (demonstration)
    1. Sharpen a flat blade screwdriver
    2. Sharpen a cold chisel
    3. Grind/Sharpen a high speed cutting bit
  C. Student practice of grinding exercises

Practical Application:

Students will begin making a Drill/Hole Gage to be finished in CNC-F4.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-F3) dealing with the operation of power saws.

CNC-F2-HO
Use Hand Tools
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

- a. Select and use hand tools;
- b. Select and use hand files;
- c. Correctly identify and use hand taps and dies as required;
- d. Select and use hand reamers;
- e. Use arbor and shop presses; and,
- f. Perform off-hand grinding operations.

Module Outline:

- I. Select and Use Hand Tools
  - A. Bench vise
  - B. Clamps
  - C. Pliers
  - D. Hammers
  - E. Wrenches
  - F. Screwdrivers
  - G. Chisels and punches
  - H. Hacksaws
- II. Select and Use Hand Files
  - A. Types of files
    - 1. Mill file
    - 2. Long angle (lathe) file
    - 3. Bastard files
  - B. Shapes of files
    - 1. Pillar files
    - 2. Square files
    - 3. Warding files
    - 4. Knife files
    - 5. Three-square files
    - 6. Half-found files
    - 7. Round files
  - C. Specialty files
    - 1. Swiss pattern files
    - 2. Die sinker's rifflers
    - 3. Curved tooth files
    - 4. Thread files
    - 5. Rotary files and burrs

        6. Scrapers
    D. Care and use of files
        1. Proper care of files
        2. Proper use of files
            a. Cross filing
            b. Draw filing
    E. Student filing practice
III. Correctly Identify and Use Hand Taps and Dies as Required
    A. Identification of taps
        1. Identifying marks on inch taps (example: ½-13-UNC)
            a. Nominal size = ½"
            b. Threads per inch = 13
            c. Standardized thread series = Unified National Coarse
        2. Identifying marks on metric taps (example: M4 X 0.7)
            a. M = metric thread
            b. Nominal diameter of the thread = 4mm
            c. Pitch of the thread = 0.7mm
        3. Standard taps
            a. Taper (starting) taps
            b. Plug taps
            c. Taper taps
        4. Special taps
            a. Pipe taps
            b. Pulley taps
            c. Acme thread taps
    B. Care and use of taps
        1. Proper care of hand taps
        2. Determining tap drill size
            a. Tap drill size chart
            b. Tap drill size formula for inch taps
                Tap Drill Size = Major Diameter of the Tap minus 1 divided by the number of threads per inch
            c. Tap drill size formula for metric taps
                Tap Drill Size = major diameter (mm) minus the pitch (mm)
        3. Demonstrate proper use of hand taps
        4. Broken tap removal
            a. Tap extractor
            b. Acid
            c. Electrical discharge
    C. Identification and use of threading dies
        1. Solid die - for chasing or recutting damaged threads
        2. Adjustable split die - for cutting threads over or under the standard depth of thread

3. Adjustable screw plate die - most efficient type of adjustable die for cutting external threads
D. Student tap and die practice
IV. Select and Use Hand Reamers
A. Types of hand reamers
1. Straight fluted reamers
2. Spiral fluted reamers
3. Expansion reamers
4. Adjustable hand reamers
5. Taper reamers
B. Care and Use of Hand Reamers
1. Proper care of hand reamers
2. Proper use of hand reamers
C. Student hand reaming practice
V. Perform Finishing Processes
A. Broaching
B. Lapping
C. Polishing
VI. Use Arbor and Shop Presses
A. To install bushings/bearings
B. To press shafts in and out of gears and sprockets
C. To seat mandrels
D. To broach keyways
E. To bend and straighten
VII. Perform Off-Hand Grinding Operations
A. Setting up the grinder (demonstration)
1. Grinding wheel selection
2. Grinding wheel "ring test"
3. Mounting the grinding wheel
4. Tool rest adjustment
5. Dressing the grinding wheel
B. Perform off-hand grinding exercises (demonstration)
1. Sharpen a flat blade screwdriver
2. Sharpen a cold chisel
3. Grind/Sharpen a high speed cutting bit
C. Student practice of grinding exercises

CNC-F2-LE
Use Hand Tools
Attachment 2: MASTER Laboratory Exercise

For this exercise, you will make a drill/hole gage.

Necessary Equipment:

- 1/8" x 2" x 8" steel bar (cold finish)
- 3/4" radius gage
- File, Double cut
- File, single cut
- Hacksaw
- Layout tools
- Steel Rule for straight edge
- Vise

I. Layout
  A. Scribe the cutting lines.
  B. Scribe the hole centers.
  C. Center punch the hole centers.

II. Cutting
  A. Leave a 1/32" lip on each cut. This lip will be filed off to finish the tool.
  B. Make sure that the workpiece is firmly in the vise and that the clearance is sufficient to allow cutting.
  B. Cut the 30° angle. Make certain that you do not cut into the body of your tool.
  C. Cut the interior edge. Make sure that you do not cut into the lip rule of your tool.

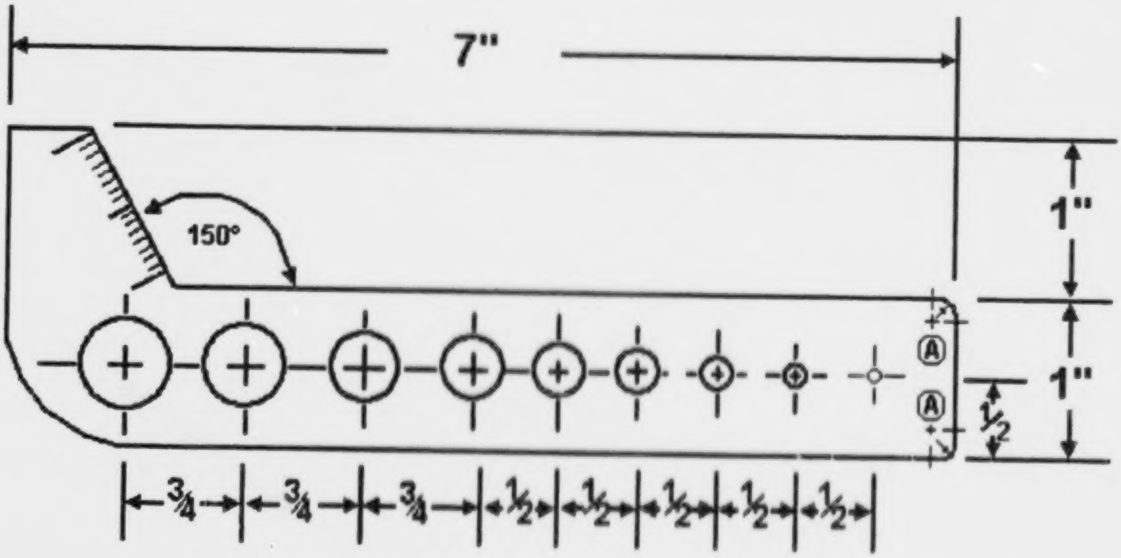
III. Filing
  A. Straight surfaces
    1. Using a single cut file, draw file all straight edges.
    2. Check the smoothness with the steel rule by holding the steel rule along one edge and looking toward a light.
    3. Continue filing the edge until almost no light is visible between the rule and the gage.
  B. 3/4" radius
    1. Clamp the workpiece securely in the vise.
    2. Using the double cut file, file off the corner, leaving a 1/32" lip for finishing.
    3. Using the single cut file, round the corner by filing forward and downward.
    4. Frequently check the finish with the 3/4" radius gage.

IV. Scribing the lip gage

A. The 30° edge should be marked at 1/16" intervals.
B. Ensure that all lines are parallel.
C. Scribe them into the edge by the method recommended by your instructor.

All Holes Bored Through
Hole Sites:
Left-to-Right
9/16"
1/2"
7/16"
3/8"
5/16"
1/4"
3/16"
1/8"
1/16"

Ⓐ 1/4" radius round



CNC-F2-LA
Use Hand Tools
Attachment 3: **MASTER** Laboratory Aid

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

Name________________________ Date______________

CNC-F2
Use Hand Tools
Self-Assessment

Circle the letter preceding the correct answer.

1. To avoid failures from seizing when pressing a shaft or mandrel, you should __________________.
    A. apply high pressure lubricant to the bore and shaft
    B. use sulfurized cutting oil on both parts
    C. use a good grade of lubricating oil on both parts and don't stop after you start pressing
    D. press them together dry

2. C-clamps are mostly used by the machinist for __________________.
    A. holding delicate measuring and layout setups
    B. clamping workpieces on the bench for filing and sawing
    C. clamping workpieces on machines such as drill presses
    D. holding vises on milling machines and drill presses

3. Parallel clamps are mostly used for __________________.
    A. holding delicate measuring and layout setups
    B. clamping workpieces on the bench for filing and sawing
    C. clamping workpieces on machines such as drill presses
    D. holding vises on milling machines and drill presses

4. The pitch of a hacksaw blade is the same as the __________________.
    A. set of the blade
    B. thickness of the blade
    C. number of teeth per inch
    D. kerf cut by a blade

5. A mill file is __________________.
    A. square
    B. milled
    C. double cut
    D. single cut

6. The edge on a file without teeth is called a __________________.
    A. straight edge
    B. safe edge
    C. smooth edge
    D. flat edge

7. Hand reamers can be readily identified by the ________________.
   A. length of the flutes
   B. length of the body
   C. markings on the shank
   D. square on the shank

8. To make a hole .002" larger than a nominal size, you should ________________.
   A. drill with a twist drill
   B. wiggle the reamer slightly in the hole
   C. ream with an expansion reamer
   D. use a spiral flute reamer

9. The size of the tap drill is important because it ________________.
   A. determines the size of the thread
   B. regulates the percentage of thread
   C. forms the major diameter
   D. determines the depth of the hole

10. A tap has the markings 7/8-9-NC on its shank. What does the 9 represent?
   A. the major diameter of the tap
   B. the minor diameter of the tap
   C. the length of the tap
   D. the number of threads per inch

CNC-F2
Use Hand Tools
Self-Assessment Answer Key

1. A
2. C
3. A
4. C
5. D
6. B
7. D
8. C
9. B
10. D

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-F3

Subject: Advanced CNC and CAM **Time: 16 Hrs.**

Duty: Perform Conventional Machining
Task: Operate Power Saws

Objective(s):

Upon completion of this unit the student will be able to:

a. Use reciprocating and horizontal band cutoff machines;
b. Operate abrasive and cold saws; and,
c. Setup and use the vertical band saw.

Instructional Materials:

MASTER Handout (CNC-F3-HO)
MASTER Laboratory Exercise 1 (CNC-F3-LE1)
MASTER Laboratory Exercise 2 (CNC-F3-LE2)
MASTER Laboratory Aid (CNC-F3-LA)
MASTER Self-Assessment
The following items are necessary for the presentation of this lesson:
Safety glasses with side shields
Face shields
Steel measuring tape
Layout dye and scribes
Power hacksaw with blades
Horizontal bandsaw with blades, vise and work stand
Abrasive cutoff saw
Vertical contour bandsaw, blades and accessories
Various bar stock and flat metals for student practice

References:

NTMA Modules:

MA-I-08	"Saws and Sawing: General Information"
MA-II-02	"Sawing: Terminology"
MA-II-04	"Sawing: Power Hacksaws and Bandsaws"
MA-II-06	"Sawing: Practices"
MA-II-08	"Sawing: Blade Preparation and Circular Saws"

Student Preparation:

Students should have previously completed the following Technical Modules:
CNC-A3 "Follow Safe Operating Procedures for Hand and Machine Tools"

Introduction:

One of the most basic types of machine shop equipment is the category of power saws. The machinist will need to be very familiar with the setup and operation of all of the types of saws commonly found in the machine shop. Power saws fall into two classifications: cutoff saws and the contour bandsaw. This lesson discusses the topics which pertain to the blade selection, setting of blade surface feet per minute and safe operation of these saws.

Presentation Outline:

I. Cutoff Type Metal Saws

   A. Four types of cutoff saws

      1. Power hacksaw - reciprocating type which cuts only on the forward stroke. It is not generally considered to be one of the most efficient cutoff machines in the machine shop.
      2. Horizontal bandsaw - uses a flexible, continuous blade which cuts continuously. They are available in a wide variety of types and sizes and are popular because of their high production and versatility.
      3. Abrasive cutoff saw - cuts metal with a thin abrasive blade which revolves at a high speed. One of it's strengths is that it can easily cut hardened metal.
      4. Friction saw - uses a saw band (usually without teeth) which is run at a very high speed (10,000 to 25,000 sfm) and burns or melts it way through metal. Ideal for cutting thin sections of structural and honeycombed parts of machine or stainless steel.

   B. Types of saw blades

      1. Material - high-speed tungsten and high-speed molybdenum steel is used for saw blades. Power hacksaws have blades which are hardened throughout while flexible blades have only the saw teeth hardened.
      2. Pitch - pitch is the number of teeth per inch. When cutting thick materials choose a saw blade with a course pitch, such as 4-6 to allow for proper chip clearance and maximum bite. When cutting thin materials choose a saw blade with a fine pitch, such as 12-14. 10 pitch is considered to be a good general purpose blade. (*Rule:* Always use a blade which will allow at least 2

teeth to be in contact with the work at all times to avoid tooth breakage.)

C. Blade removal and installation
   1. Always turn the electrical power off
   2. Use a brush to clean the areas (guides) through which the blade must pass
   3. Carefully release any blade tensioning device and remove the blade
   4. Select the correct blade for the cutting job at hand
   5. Install the blade with the teeth facing in the proper cutting direction
   6. Tighten the blade tensioning device checking that the blade is properly aligned and tensioned
   7. Quickly start and stop the saw to verify proper operation
   8. For saws which have adjustable speeds, set the proper cutting speed for the metal to be cut

D. Operation
   1. Check vise mounting for tightness and squareness to the cutting blade
   2. Place material in the vise (support long pieces with a floor stand)
   3. Lower the saw blade until it is close to the work
   4. Adjust any blade guides until they just clear the sides of the material to be cut
   5. Measure the part to be cut, allowing 1/16" or more for saw run-out
   6. Tighten the vise, check length measurement and turn the saw on

E. Sawing hints
   1. Never attempt to mount, measure, or remove work unless the saw is stopped
   2. Guard long material at both ends to prevent anyone from coming in contact with it
   3. Use cutting fluid when possible to help prolong the life of the saw blade
   4. When several pieces of the same length are to be cut, set the stop gage to the desired length
   5. If the blade dulls or breaks, re-start the cut in a new place

F. Student practice
   1. Students should select proper pitch blade for a cutting application
   2. Students should practice removal/installation of a saw blade
   3. Students should use the saw to cut a piece of metal to length
   4. Students should operate abrasive and cold saws if available

II. The Vertical Contour Bandsaw

A. Description of the contour bandsaw parts and accessories
  1. Base
  2. Column
  3. Head
B. Bandsaw Applications
  1. Notching
  2. Slotting
  3. Splitting
  4. Radius cutting
  5. Angular cutting
  6. Three-dimensional shaping
C. Blade Variables/Types (the text has excellent illustrations for each of these)
  1. Tooth forms -
    a. Precision or regular
    b. Claw or hook tooth
    c. Buttress or skip tooth
  2. Pitch - the number of teeth per inch (see above discussion at I,B,2)
  3. Set - amount of side to side offset of the teeth for clearance
    a. Wave
    b. Straight
    c. Raker
  4. Width - the distance from the tip of the teeth to the back of the blade
    a. For making straight cuts, select a wide blade
    b. For cutting small radii, select a narrow blade
    c. For general cutting, select the widest blade which can cut the smallest radius on the workpiece
  5. Gage - the thickness of the saw blade
D. Bandsaw operation
  1. Instructor demonstration of the following
    a. Blade removal/assembly
      1. Unfolding/folding saw blades
      2. Measuring and cutting stock saw blade material
      3. Welding a saw blade using the band welder
    b. Cutting speed adjustment
    c. Saw guide adjustments
    d. Careful operation of the bandsaw
  2. Student practice of the following steps
    a. Blade removal/assembly
      1. Unfolding/folding saw blades
      2. Measuring and cutting stock saw blade material
      3. Welding a saw blade using the band welder
    b. Cutting speed adjustment

    c. Saw guide adjustments
    d. Careful operation of the bandsaw

III. Cleanup and Review of Main Lesson Points

Practical Application:

The students will work under instructor supervision to perform each of the tasks outlined in the lesson outline, in a safe, efficient manner.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson. In addition, students will use each of the machines discussed and cut pieces of material to a tolerance of ± 1/16".

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-F4) dealing with the operation of drill presses.

CNC-F3-HO
Operate Power Saws
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Use reciprocating and horizontal band cutoff machines;
b. Operate abrasive and cold saws; and,
c. Setup and use the vertical band saw.

Module Outline:

I. Cutoff Type Metal Saws
  A. Four types of cutoff saws
    1. Power hacksaw - reciprocating type which cuts only on the forward stroke. It is not generally considered to be one of the most efficient cutoff machines in the machine shop.
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  B. Types of saw blades
    1. Material - high-speed tungsten and high-speed molybdenum steel is used for saw blades. Power hacksaws have blades which are hardened throughout while flexible blades have only the saw teeth hardened.
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  C. Blade removal and installation
    1. Always turn the electrical power off

      2. Use a brush to clean the areas (guides) through which the blade must pass
      3. Carefully release any blade tensioning device and remove the blade
      4. Select the correct blade for the cutting job at hand
      5. Install the blade with the teeth facing in the proper cutting direction
      6. Tighten the blade tensioning device checking that the blade is properly aligned and tensioned
      7. Quickly start and stop the saw to verify proper operation
      8. For saws which have adjustable speeds, set the proper cutting speed for the metal to be cut

   D. Operation
      1. Check vise mounting for tightness and squareness to the cutting blade
      2. Place material in the vise (support long pieces with a floor stand)
      3. Lower the saw blade until it is close to the work
      4. Adjust any blade guides until they just clear the sides of the material to be cut
      5. Measure the part to be cut, allowing 1/16" or more for saw run-out
      6. Tighten the vise, check length measurement and turn the saw on

   E. Sawing hints
      1. Never attempt to mount, measure, or remove work unless the saw is stopped
      2. Guard long material at both ends to prevent anyone from coming in contact with it
      3. Use cutting fluid when possible to help prolong the life of the saw blade
      4. When several pieces of the same length are to be cut, set the stop gage to the desired length
      5. If the blade dulls or breaks, re-start the cut in a new place

   F. Student practice
      1. Students should select proper pitch blade for a cutting application
      2. Students should practice removal/installation of a saw blade
      3. Students should use the saw to cut a piece of metal to length
      4. Students should operate abrasive and cold saws if available

II. The Vertical Contour Bandsaw

   A. Description of the contour bandsaw parts and accessories
      1. Base
      2. Column
      3. Head

- B. Bandsaw Applications
    - 1. Notching
    - 2. Slotting
    - 3. Splitting
    - 4. Radius cutting
    - 5. Angular cutting
    - 6. Three-dimensional shaping
- C. Blade Variables/Types (the text has excellent illustrations for each of these)
    - 1. Tooth forms -
        - a. Precision or regular
        - b. Claw or hook tooth
        - c. Buttress or skip tooth
    - 2. Pitch - the number of teeth per inch (see above discussion at I,B,2)
    - 3. Set - amount of side to side offset of the teeth for clearance
        - a. Wave
        - b. Straight
        - c. Raker
    - 4. Width - the distance from the tip of the teeth to the back of the blade
        - a. For making straight cuts, select a wide blade
        - b. For cutting small radii, select a narrow blade
        - c. For general cutting, select the widest blade which can cut the smallest radius on the workpiece
    - 5. Gage - the thickness of the saw blade
- D. Bandsaw operation
    - 1. Instructor demonstration of the following
        - a. Blade removal/assembly
            - 1. Unfolding/folding saw blades
            - 2. Measuring and cutting stock saw blade material
            - 3. Welding a saw blade using the band welder
        - b. Cutting speed adjustment
        - c. Saw guide adjustments
        - d. Careful operation of the bandsaw
    - 2. Student practice of the following steps
        - a. Blade removal/assembly
            - 1. Unfolding/folding saw blades
            - 2. Measuring and cutting stock saw blade material
            - 3. Welding a saw blade using the band welder
        - b. Cutting speed adjustment
        - c. Saw guide adjustments
        - d. Careful operation of the bandsaw

III. Cleanup and Review of Main Lesson Points

CNC-F3-LE1

Operate Power Saws

Attachment 2: **MASTER** Laboratory Exercise No. 1

Laboratory Exercise No. 1:

1. Instructor will demonstrate how to setup and operate a band saw to a designated tolerance without endangering personnel or equipment by:
   - A. Selecting proper blade;
   - B. Installing and properly adjusting the blade;
   - C. Adjusting the blade guides and guard;
   - D. Adjusting the coolant flow if or as appropriate;
   - E. Adjusting feed control (if applicable);
   - F. Properly securing the work and making a cut to specified tolerances; and,
   - G. Shutting down the machine and cleaning up work area.

2. Student will demonstrate how to setup and operate a band saw to a designated tolerance without endangering personnel or equipment by:
   - A. Selecting proper blade;
   - B. Installing and properly adjusting the blade;
   - C. Adjusting the blade guides and guard;
   - D. Adjusting the coolant flow if or as appropriate;
   - E. Adjusting feed control (if applicable);
   - F. Properly securing the work and making a cut to specified tolerances; and,
   - G. Shutting down the machine and cleaning up work area.

3. Instructor will grade student's performance.

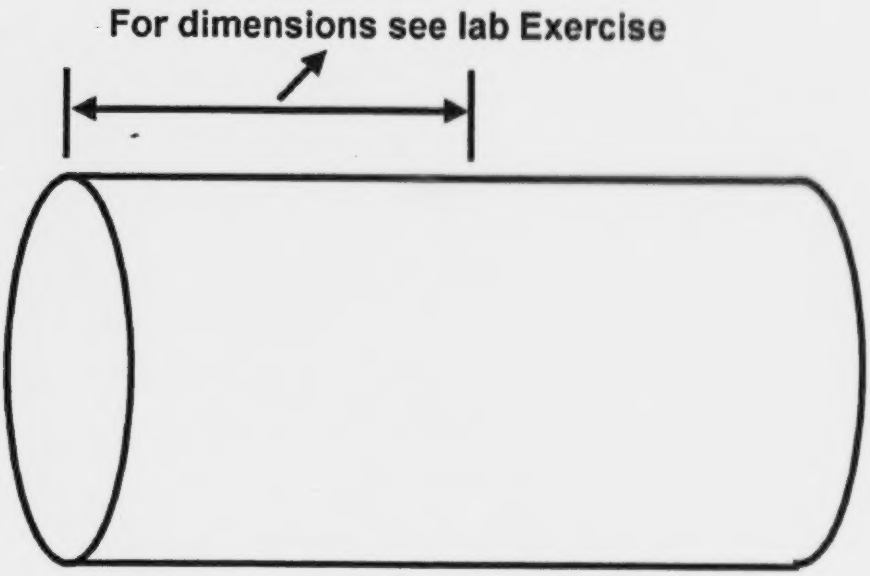
CNC-F3-LE2
Operate Power Saws
Attachment 3: **MASTER** Laboratory Exercise No. 2

Laboratory Exercise No. 2:

Using each of the saws discussed in the module, the student will cut five workpieces, in different metals or grades of steel. The required accuracy is +/-1/16".

The following five lengths should be cut by each student:

1. 4"
2. 2.5"
3. 40 mm
4. 5 1/8"
5. 50 mm



Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
   a. No loose clothing, including ties;
   b. Long hair properly stowed;
   c. No jewelry;
   d. Hard, closed-toe shoes;
   e. Eye protection (safety glasses); and,
   f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

Name____________________________ Date_______________

CNC-F3
Operate Power Saws
Self-Assessment

Circle the letter preceding the correct answer.

1. Which of the following is *not* normally classified as a cutoff saw?
   - A. Horizontal bandsaw
   - B. Contour bandsaw
   - C. Power hacksaw
   - D. Abrasive saw

2. Which type of saw is most productive when preparing bar stock for machining operations?
   - A. Horizontal bandsaw
   - B. Contour bandsaw
   - C. Power hacksaw
   - D. Abrasive saw

3. Which type of saw is most useful for sawing parts having unusual angles and radii?
   - A. Horizontal bandsaw
   - B. Contour bandsaw
   - C. Power hacksaw
   - D. Abrasive saw

4. Which of the following refers to the number of teeth per inch for a saw blade?
   - A. Set
   - B. Gage
   - C. TPI
   - D. Pitch

5. Using your answer to question 4, which is best for general purpose sawing?
   - A. 4
   - B. 6
   - C. 10
   - D. 14

6. Which type of sawing can be done using a blade with no teeth?
   - A. Precision
   - B. Soft materials
   - C. Abrasive
   - D. Friction

7. What happens if too fast a blade speed is used?
   A. You finish the job sooner
   B. You burn up the saw blade
   C. You increase production
   D. You injure yourself

8. What do you do if the saw blade dulls or breaks before the cut is completed?
   A. Stop the saw
   B. Replace the blade with a new one
   C. Re-start the cut in a new location
   D. All of the above

9. How is the blade speed adjusted on a contour bandsaw?
   A. Change the belts
   B. Change the blade
   C. Adjust the handwheel
   D. Adjust the blade supports and guides

10. Which of the following is *not* a requirement of a sawing job?
   A. Speed
   B. Safety
   C. Tool life
   D. Accuracy

CNC-F3
Operate Power Saws
Self-Assessment Answer Key

1. B
2. A
3. A
4. D
5. C
6. D
7. B
8. D
9. C
10. A

CNC-F4

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-F4

Subject: **Advanced CNC and CAM** **Time: 20 Hrs.**

Duty: **Perform Conventional Machining**
Task: Operate Drill Presses

Objective(s):

Upon completion of this unit the student will be able to:

a. Describe the different types of drill presses found in the machine shop;
b. Select and use the standard drilling machine accessories;
c. Select and use standard drilling tools;
d. Sharpen a drill bit using a bench or pedestal grinder; and,
e. Layout, setup and perform these drilling operations: drilling, tapping, countersinking, counterboring, reaming.

Instructional Materials:

MASTER Handout (CNC-F4-HO)
MASTER Laboratory Exercise No. 1 (CNC-F4-LE1)
MASTER Laboratory Exercise No. 2 (CNC-F4-LE2)
MASTER Laboratory Aid (CNC-F4-LA)
MASTER Self-Assessment
The following items are necessary for the presentation of this lesson:
Safety glasses for each student
Drill presses (with tool holding & work holding devices)
Twist drills, taps, reamers with accessories
Various sizes & shapes of different metals for student practice

References:

NTMA Modules:

MA-I-10	"Drill Press: General Information"
MA-I-12	"Drill Press: Drill Bits"
MA-I-14	"Drill Press: Reamers & Drilling Operations"

Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-F1	"Prepare and Plan For Machining Operations"
CNC-F2	"Use Hand Tools"

Introduction:

One of the most important machines that the machinist may be called on to operate is a drilling machine. The principle of a rotating tool producing a hole in a workpiece is very basic to all machine operations. Not only are drill presses used to produce holes, but they are also capable of threading, countersinking, reaming, boring, counterboring, and many other operations necessary for the production of goods in American industry today. Many entry-level machine operators and machinists will find their first job to be that of a drill press operator.

Presentation Outline:

- I. Describe the Different Types of Drill Presses Found in the Machine Shop
  - A. Sensitive drill press
  - B. Upright drill press
  - C. Radial drill press
  - D. CNC drilling machines
- II. Select and Use the Standard Drilling Machine Accessories
  - A. Tool-holding devices
    - 1. Drill chucks
    - 2. Drill sockets, sleeves and drifts
  - B. Work-holding devices
    - 1. Drill vise
    - 2. V-blocks
    - 3. Angle plate
    - 4. Clamps and straps
- III. Select and Use Standard Drilling Tools
  - A. Twist drills
    - 1. Shank
    - 2. Body
    - 3. Points
    - 4. Sizes
      - a. Fractional size drills
      - b. Number size drills
      - c. Letter size drills
      - d. Metric drills
    - 5. Special types of drills
      - a. Straight-fluted
      - b. Spade drills
      - c. Deep hole drills
      - d. Core drills
    - 6. Cutting fluids
      - a. Drilling
      - b. Tapping

  - B. Sharpen a drill bit using a bench or pedestal grinder
    - 1. Review grinder safety
    - 2. Discuss the following drill point characteristics
      - a. Chisel edge
      - b. Lip clearance
      - c. Lip length
      - d. Web thinning
    - 3. Demonstrate this for the students
    - 4. Student practice
- IV. Layout, Setup and Perform These Drilling Operations:
  - A. Drilling
    - 1. Speed (rpm) - discuss the formula.....CS X 4 ÷ diam. = RPM
    - 2. Feed (inch per revolution) - roughing and finishing
  - B. Countersinking
  - C. Counterboring
  - D. Reaming
    - 1. Discuss reaming allowance
    - 2. Speed is normally twice that used for drilling
    - 3. Feed is normally ½ that used for drilling
  - E. Tapping
    - 1. Discuss tap drill size
    - 2. Discuss special taps for machine tapping

Practical Application:

Students will successfully complete the drill press exercises required for this module's laboratory exercises. Several exercises may be found in the student workbook, or the instructor may develop special activities which will utilize the resources for a given laboratory or for a given level of students (beginning, intermediate or advanced).

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-F5) dealing with the setup and operation of the vertical milling machine.

CNC-F4-HO
Operate Drill Presses
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Describe the different types of drill presses found in the machine shop;
b. Select and use the standard drilling machine accessories;
c. Select and use standard drilling tools;
d. Sharpen a drill bit using a bench or pedestal grinder; and,
e. Layout, setup and perform these drilling operations: drilling, tapping, countersinking, counterboring, reaming.

Module Outline:

I. Describe the Different Types of Drill Presses Found in the Machine Shop
    A. Sensitive drill press
    B. Upright drill press
    C. Radial drill press
    D. CNC drilling machines
II. Select and Use the Standard Drilling Machine Accessories
    A. Tool-holding devices
        1. Drill chucks
        2. Drill sockets, sleeves and drifts
    B. Work-holding devices
        1. Drill vise
        2. V-blocks
        3. Angle plate
        4. Clamps and straps
III. Select and Use Standard Drilling Tools
    A. Twist drills
        1. Shank
        2. Body
        3. Points
        4. Sizes
            a. Fractional size drills
            b. Number size drills
            c. Letter size drills
            d. Metric drills
        5. Special types of drills
            a. Straight-fluted
            b. Spade drills
            c. Deep hole drills

        - d. Core drills
    - 6. Cutting fluids
        - a. Drilling
        - b. Tapping
- B. Sharpen a drill bit using a bench or pedestal grinder
    - 1. Review grinder safety
    - 2. Discuss the following drill point characteristics
        - a. Chisel edge
        - b. Lip clearance
        - c. Lip length
        - d. Web thinning
    - 3. Demonstrate this for the students
    - 4. Student practice

IV. Layout, Setup and Perform These Drilling Operations:

- A. Drilling
    - 1. Speed (rpm) - discuss the formula.....CS X 4 ÷ diam. = RPM
    - 2. Feed (inch per revolution) - roughing and finishing
- B. Countersinking
- C. Counterboring
- D. Reaming
    - 1. Discuss reaming allowance
    - 2. Speed is normally twice that used for drilling
    - 3. Feed is normally ½ that used for drilling
- E. Tapping
    - 1. Discuss tap drill size
    - 2. Discuss special taps for machine tapping

CNC-F4-LE1
Operate Drill Presses
Attachment 2: MASTER Laboratory Exercise No. 1

Laboratory Exercise No. 1:

Each student will be assigned two workpieces, made of either two different metals or two greatly different grades of steel.

1. For the first piece, the student will drill, ream, *counterbore*, and tap the following holes:
   - A. 3/16"
   - B. 1/2"
   - C. 5/8"
   - D. 4mm
   - E. 12mm

2. For the second piece, the student will drill, ream, *countersink*, and tap the following holes:
   - A. 3/16"
   - B. 1/2"
   - C. 5/8"
   - D. 4mm
   - E. 12mm

CNC-F4-LE2

Operate Drill Presses

Attachment 3: **MASTER** Laboratory Exercise No. 2

Laboratory Exercise No. 2:

You will now complete your Drill/Hole Gage.

Necessary Equipment:

- #2 Center Drill
- Countersinks of appropriate sizes
- Drill Bits: 9/16", 1/2", 7/16", 3/8", 5/16", 1/4", 3/16", 1/8", 1/16"
- Set of Parallels
- Vise

I. Test the drill bits which you will use. Sharpen them as necessary.

II. Set up the gage and the parallels in the vise so that the 3/4" bit will clear through the gage.

III. With the machine OFF, emplace the center drill. The drill should be centered for the 3/4" hole.

IV. *Without moving the workpiece,* tighten the vise.

V. Drilling

  A. Set the machine to the correct speed for the drill size you are using.

  B. Spot drill all the holes *except* the 1/16" hole. (Spot drilling this hole may cause it to be over size in the finished tool).

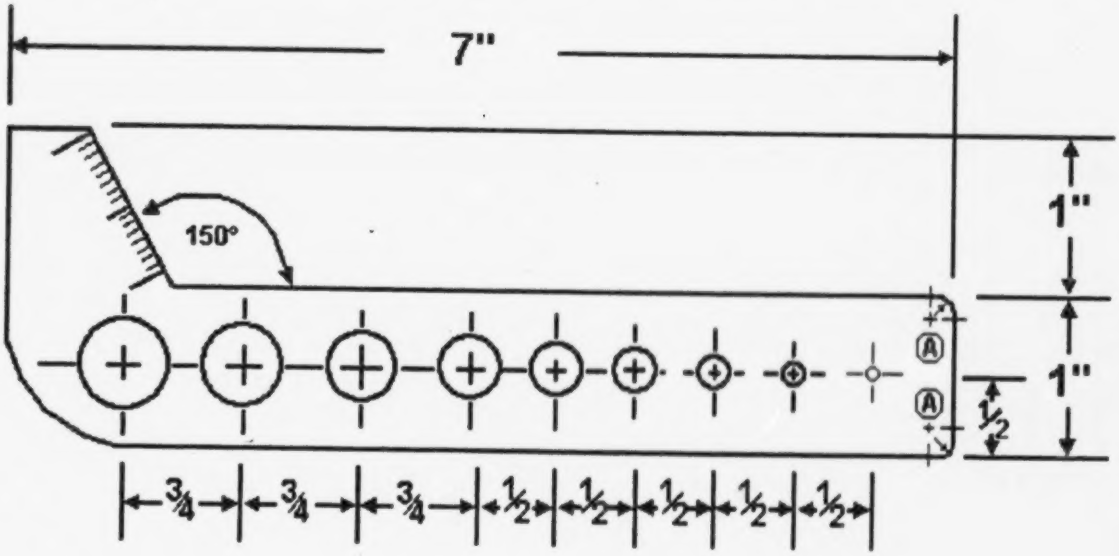
  C. Change to the 1/16" bit and drill the hole.

  D. Change to the 1/8" bit and drill that hole. Using the 1/8" bit, pilot drill all larger holes.

  E. Drill the other holes.

  F. Be sure to check the machine speed for each drill size. Adjust the machine speed as necessary.

VI. Countersink each side of each hole. A minimal chamfer is all that is required.


7"
150°
1"
1"
Ⓐ
Ⓐ
½
¾
¾
¾
½
½
½
½
½

All Holes Bored Through

Hole Sites:

Left-to-Right

- 9/16"
- 1/2"
- 7/16"
- 3/8"
- 5/16"
- 1/4"
- 3/16"
- 1/8"
- 1/16"

Ⓐ 1/4" radius round

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
   a. No loose clothing, including ties;
   b. Long hair properly stowed;
   c. No jewelry;
   d. Hard, closed-toe shoes;
   e. Eye protection (safety glasses); and,
   f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

Name______________________ Date______________

CNC-F4
Operate Drill Presses
Self-Assessment

Circle the letter preceding the correct answer.

1. Which of the following types of drill presses would be best suited for high volume production parts?
   - A. CNC drilling machine
   - B. sensitive drill press
   - C. radial drill press
   - D. gang drilling machine

2. Taper shank twist drills are mounted in the drill press using a ______________.
   - A. drill spindle
   - B. drill sleeve
   - C. drill socket
   - D. all of the above

3. How is a tapered shank drill removed from a drill press spindle?
   - A. with a reversible drill socket
   - B. with a drill drift
   - C. with a ball peen hammer
   - D. with a spindle remover

4. A conventional drill point usually has an included angle of ____________.
   - A. 60°
   - B. 90°
   - C. 118°
   - D. 135°

5. Which of the following types of drill bits has a removable cutting bit?
   - A. a core drill
   - B. a gun drill
   - C. a spade drill
   - D. a variable size drill

6. When a drill bit shows excessive wear at the outer corners of the point, the problem will usually be ______________.
   - A. improper web thinning
   - B. cutting lips with unequal angles
   - C. excessive feed
   - D. excessive speed

7. When a drill bit produces a hole which is excessively oversize, the problem will usually be _______________.
A. improper web thinning
B. cutting lips with unequal angles
C. cutting lips with unequal lengths
D. excessive feed

8. To make it easier for a drill bit to do it's work, which of the following will help greatly?
A. thin the web of the drill
B. use coolant
C. inspect the drill bit
D. all of the above

9. Which of the following factors affect the rate of feed chosen for a job?
A. the diameter of the drill
B. the material of the workpiece
C. the condition of the drilling machine
D. all of the above

10. As a general rule; for holes up to ½" diameter, allow _________ for reaming and for holes over ½" diameter, allow _________ for reaming.
A. 1/64" , 1/32"
B. 1/32" , 1/64"
C. .100" , .200"
D. none of the above

11. Which of the following types of taps cannot be used with the drill press?
A. a gun tap
B. a spiral-fluted tap
C. a hand tap
D. a tap drill

12. Which of the following is not a valid system of drill sizing?
A. fractional drills
B. taper drills
C. metric drills
D. letter drills

CNC-F4
Operate Drill Press
Self-Assessment Answer Key

1. A
2. D
3. B
4. C
5. C
6. D
7. C
8. D
9. D
10. A
11. D
12. B

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-F5

Subject: **Advanced CNC and CAM** **Time: 40 Hrs.**

Duty: **Perform Conventional Machining**
Task: Operate Vertical Milling Machines

Objective(s):

Upon completion of this unit the student will be able to:
a. Demonstrate the use of all controls on the vertical milling machine;
b. Align the vertical milling machine head;
c. Select, align, and use workholding devices;
d. Select milling tool holders;
e. Select milling cutters;
f. Perform all standard vertical milling operations;
g. Bore a hole using the offset boring head;
h. Machine angles using sine bar and gage blocks;
i Machine keyways; and,
j. Setup and machine dovetails.

Instructional Materials:

MASTER Handout (CNC-F5-HO)
MASTER Laboratory Exercise (CNC-F5-LE)
MASTER Laboratory Aid (CNC-F5-LA)
MASTER Self-Assessment
Vertical milling machine
Representative milling cutters, tool holders, etc.
Samples of metals to be milled

References:

Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition, "Vertical Milling Machines"
Machinery's Handbook, Industrial Press, Latest Edition

Student Preparation:

Students should have previously completed the following Technical Modules:
CNC-A1 through CNC-A5 "Practice Safety"
CNC-B7 "Calculate Speeds and Feeds for Machining"

CNC-E3 "Measure With Hand Held Instruments"
CNC-F1 "Prepare and Plan For Machining Operations"

Introduction:

At less than 150 years in use, the highly versatile vertical mill is one of the newest of the conventional machine tools. The machine has really come into its own since the 1920's.

Presentation Outline:

I. Identify Parts and Use All Controls on the Vertical Milling Machine
    A. Base
    B. Column
    C. Knee
    D. Saddle
    E. Table
    F. Ram
    G. Toolhead
    H. Motor
    I. Turret Clamps
    J. Quill, Quill Jack, and Spindle
    K. Controls
        1. Forward/Reverse Motor Switch
        2. Spindle Brake
        3. Power Feed Change Lever
        4. Quill Feed Handwheel
        5. Feed Control Lever
        6. Quill Feed Hand Lever
        7. Feed Reverse Knob
        8. High/Low Speed Change Lever
        9. Variable Speed Control Wheel
        10. Table Reverse Crank
        11. Vertical Traverse Crank
        12. Cross Traverse Crank
        13. Table Power Feed
    L. Locks and Gib Adjusting Screws
II. Setup Milling Machine
    A. Square the Toolhead to Table and Saddle Axes
    B. Select, Align, and Use Workholding Devices
        1. Direct Table Mounting
        2. Mill Vises
        3. Work Edge and Hole Centerline Locating
    C. Select Milling Tool Holders

    - 1. Solid Collet
    - 2. Split Collet
    - 3. Quick-Change Systems
    - 4. Arbor
  - D. Select Milling Cutters
    - 1. High-Speed Steel Helical End Mills
    - 2. HSS Straight-Flute End Mills
    - 3. Carbide EMs
    - 4. Roughing and Tapering EMs
    - 5. Geometry-Forming EMs
    - 6. Dovetail EMs
    - 7. T-Slot EMs
    - 8. Woodruff Key EMs
    - 9. Shell End Mills
    - 10. Flycutters
- VI. Perform All Standard Vertical Milling Operations
  - A. Basic Operations and Terms
    - 1. Climb Milling vs Conventional Milling
    - 2. Factors Affecting Cutting Performance
    - 3. Cutting Fluids
      - a. Purpose and Use
      - b. Selection
      - c. Safety
  - D. Milling Cavities
  - E. Angle Milling
  - F. Drilling
- VII. Bore a Hole Using the Offset Boring Head
  - A. Identify Parts of Boring Head
  - B. Workpiece Setup
  - C. Tool Selection
  - D. Use the Offset Boring Head
- VIII. Machine Angles Using Sine Bar and Gage Blocks
  - A. Identify Parts
    - 1. Sine Bar
    - 2. Sine Plate
    - 3. Use and Care of Gage Blocks
- IX. Machine Keyways
- X. Setup and Machine Dovetails and T-Slots

Practical Application:

Students will be able to perform the basic milling operations as demonstrated by the instructor. The student will identify all the parts of the machine, and the types of cutters and their uses.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-F6) dealing with the setup and operation of the horizontal milling machine.

CNC-F5-HO
Operate Vertical Milling Machines
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Demonstrate the use of all controls on the vertical milling machine;
b. Align the vertical milling machine head;
c. Select, align, and use workholding devices;
d. Select milling tool holders;
e. Select milling cutters;
f. Perform all standard vertical milling operations;
g. Bore a hole using the offset boring head;
h. Machine angles using sine bar and gage blocks;
i Machine keyways; and,
j. Setup and machine dovetails.

Module Outline:

I. Identify Parts and Use All Controls on the Vertical Milling Machine
   A. Base
   B. Column
   C. Knee
   D. Saddle
   E. Table
   F. Ram
   G. Toolhead
   H. Motor
   I. Turret Clamps
   J. Quill, Quill Jack, and Spindle
   K. Controls
      1. Forward/Reverse Motor Switch
      2. Spindle Brake
      3. Power Feed Change Lever
      4. Quill Feed Handwheel
      5. Feed Control Lever
      6. Quill Feed Hand Lever
      7. Feed Reverse Knob
      8. High/Low Speed Change Lever
      9. Variable Speed Control Wheel
      10. Table Reverse Crank
      11. Vertical Traverse Crank
      12. Cross Traverse Crank

        - 13. Table Power Feed
    - L. Locks and Gib Adjusting Screws
- II. Setup Milling Machine
    - A. Square the Toolhead to Table and Saddle Axes
    - B. Select, Align, and Use Workholding Devices
        - 1. Direct Table Mounting
        - 2. Mill Vises
        - 3. Work Edge and Hole Centerline Locating
    - C. Select Milling Tool Holders
        - 1. Solid Collet
        - 2. Split Collet
        - 3. Quick-Change Systems
        - 4. Arbor
    - D. Select Milling Cutters
        - 1. High-Speed Steel Helical End Mills
        - 2. HSS Straight-Flute End Mills
        - 3. Carbide EMs
        - 4. Roughing and Tapering EMs
        - 5. Geometry-Forming EMs
        - 6. Dovetail EMs
        - 7. T-Slot EMs
        - 8. Woodruff Key EMs
        - 9. Shell End Mills
        - 10. Flycutters
- VI. Perform All Standard Vertical Milling Operations
    - A. Basic Operations and Terms
        - 1. Climb Milling vs Conventional Milling
        - 2. Factors Affecting Cutting Performance
        - 3. Cutting Fluids
            - a. Purpose and Use
            - b. Selection
            - c. Safety
    - D. Milling Cavities
    - E. Angle Milling
    - F. Drilling
- VII. Bore a Hole Using the Offset Boring Head
    - A. Identify Parts of Boring Head
    - B. Workpiece Setup
    - C. Tool Selection
    - D. Use the Offset Boring Head
- VIII. Machine Angles Using Sine Bar and Gage Blocks
    - A. Identify Parts
        - 1. Sine Bar
        - 2. Sine Plate
        - 3. Use and Care of Gage Blocks

IX. Machine Keyways
X. Setup and Machine Dovetails and T-Slots

CNC-F5-LE
Operate Vertical Milling Machines
Attachment 2: MASTER Laboratory Exercise

I. The student should align the vertical milling machine head.

II. The student should mill the following forms:
  - A. A keyseat in a shaft;
  - B. A set of short (no more than 18") dovetail joints;
  - C. A cavity in a block; and,
  - D. A T-slot in a block 6" long; the T-slot must be parallel to the long side of the block.

III. Evaluation criteria:
  - A. The chosen key must fit properly in the keyseat;
  - B. The dovetailed workpieces must mate properly;
  - C. The cavity in the block must be within the tolerances established by the instructor; and,
  - D. The T-slot must accept and freely pass the selected commercial T-nut.

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

Name______________________________ Date_______________

CNC-F5
Operate Vertical Milling Machines
Self-Assessment

Circle the letter preceding the correct answer.

1. The saddle is moved with the:
   - A. Cross traverse handle.
   - B. Vertical traverse crank.
   - C. Knee slide.
   - D. The saddle is immobile.
   - E. None of the above answers is correct.

2. The vertical mill's engine is located in the:
   - A. Base.
   - B. Column.
   - C. Toolhead.
   - D. Ram.
   - E. None of the above answers is correct.

3. The ball-end mill is used to cut:
   - A. Concave radii.
   - B. Convex radii.
   - C. Interior fillets.
   - D. Both A and C.
   - E. Both B and C.

4. T-slot cutters:
   - A. Are standard.
   - B. Fit standard T-*nuts*.
   - C. Cut the T-slots in machine tables and workholders.
   - D. All of the above answers are correct.
   - E. None of the above answers is correct.

5. An end mill holder is also called a:
   - A. Solid collet.
   - B. R-8 spindle.
   - C. Split collet.
   - D. Shell arbor.
   - E. None of the above answers is correct.

6. The major difficulty in using a split collet is:
   A. The looseness of the collet on the shank.
   B. The tendency of the tool to come out if the tool is turning too rapidly.
   C. The tool may pull out if the tool is dull.
   D. All of the above are problems involving split collets.
   E. None of the above answers is correct.

7. Machinist A says that the dovetail slide on the face of the column provides a guide for the knee. Machinist B says that single-angle milling cutters are used, usually in either 45° or 90° forms, to cut dovetails. Who is correct?
   A. Machinist A only
   B. Machinist B only
   C. Both machinists are correct.
   D. Neither machinist is correct.

8. Machinist A says that the flycutter is dangerous to use because the tool becomes almost invisible at high speed. Machinist B says that the flycutter, while not actually an end mill, is useful for making light face cuts on large areas. Who is correct?
   A. Machinist A only
   B. Machinist B only
   C. Both machinists are correct.
   D. Neither machinist is correct.

9. Some vertical mills are equipped with ___ jaws, used when it is necessary to shape the jaws to fit particular workpieces.
   A. Aluminum
   B. Tool steel
   C. Bronze
   D. Wrought iron
   E. None of the above answers is correct.

10. In *climb* or *down* milling, the cutter rotates ___ the feed; in *conventional* or *up* milling, the cutter rotates ___ the feed.
   A. Opposite to. . opposite to
   B. Opposite to. . .in the same direction as
   C. In the same direction as. . .opposite to
   D. In the same direction as. . .in the same direction as
   E. None of the above answers is correct.

CNC-F5
Operate Vertical Milling Machines
Self-Assessment Answer Key

1. A
2. C
3. D
4. D
5. A
6. C
7. A
8. C
9. A
10. C

CNC-F6

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-F6

Subject: **Advanced CNC and CAM** **Time: 32 Hrs.**

Duty: **Perform Conventional Machining**
Task: Operate Horizontal Milling Machines

Objective(s):

Upon completion of this unit the student will be able to:

a. Discuss the difference in plain and universal horizontal milling machines;
b. Discuss the types of spindles, arbors and adaptors used on the horizontal milling machine;
c. List several common work holding methods;
d. Use plain milling cutters;
e. Use side milling cutters; and,
f. Use face milling cutters.

Instructional Materials:

MASTER Handout (CNC-F6-HO)
MASTER Laboratory Exercise (CNC-F6-LE)
MASTER Laboratory Aid (CNC-F6-LA)
MASTER Self-Assessment

References:

Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition, "Horizontal Milling Machines"

Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-A1 through CNC-A5 "Practice Safety"
CNC-B7 "Calculate Speeds and Feeds for Machining"
CNC-E3 "Measure With Hand Held Instruments"
CNC-F1 "Prepare and Plan for Machining Operations"

Introduction:

The horizontal mill varies in size from small models found in almost all shops to huge machines the size of small buildings. As is evident from the huge differences in sizes of horizontal mills, they have a number of applications which cannot be adequately controlled by one person. The larger mills require teamwork to load their stock and to unload the finished parts. In situ inspections may also require more than one person to effectively and efficiently operate these titanic machines.

Presentation Outline:

- I. Discuss the Difference in Plain and Universal Horizontal Milling Machines
  - A. Determine Machine Size
  - B. Identify Parts & Controls
    - 1. Base and Column
    - 2. Knee
    - 3. Saddle
    - 4. Table
    - 5. Spindle
    - 6. Overarm and Arbor Support
    - 7. Controls
      - a. Manual movement controls
      - b. Feed rate selector and feed engage
      - c. Rapid traverse
      - d. Spindle controls
      - e. Locks
    - 8. Swivel housing on saddle of Universal Milling Machine
- II. Discuss the Types of Spindles, Arbors, and Adaptors Used on the Horizontal Milling Machine
  - A. Mill Spindle Tapers
  - B. Arbors
    - 1. Style A
    - 2. Style B
    - 3. Style C
    - 4. Spacing Collars
    - 5. Bearing Collars
    - 6. Support Bearings
  - C. Adapters
  - D. Collets
  - E. Quick-Change Systems
- III. List Several Common Work Holding Methods
  - A. Direct Table Mounts
    - 1. Clamp supports
    - 2. Screw jacks

- B. Mill Vises
- C. Miscellaneous Holders
    - 1. Rotary table
    - 2. Dividing head
    - 3. V-Blocks
    - 4. Specially made milling fixtures

IV. Use Plain Milling Cutters
- A. Roughing
- B. Squaring
- C. Milling Endpieces

V. Use Side Milling Cutters
- A. Setup
- B. Positioning the Cutter
- C. Making the Cut
    - 1. Keyseats
    - 2. Straddle and Gang Milling
- D. Helical Side Milling Cutters
    - 1. Uses
    - 2. Handedness

VI. Use Face Milling Cutters
- A. Composition and Inserts
- B. Uses
- C. Lead Angles and Rake Angles
- D. Wiper Flats

Practical Application:

Students shall be able to use the three types of cutters listed above; recognize and utilize the various spindles, arbors, and adaptors; and set up workpieces appropriately.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment and the Laboratory Exercise found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-F7) dealing with the setup and operation of a metal cutting engine lathe.

CNC-F6-HO
Operate Horizontal Milling Machines
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Discuss the difference in plain and universal horizontal milling machines;
b. Discuss the types of spindles, arbors and adaptors used on the horizontal milling machine;
c. List several common work holding methods;
d. Use plain milling cutters;
e. Use side milling cutters; and,
f. Use face milling cutters.

Module Outline:

I. Discuss the Difference in Plain and Universal Horizontal Milling Machines
  A. Determine Machine Size
  B. Identify Parts & Controls
    1. Base and Column
    2. Knee
    3. Saddle
    4. Table
    5. Spindle
    6. Overarm and Arbor Support
    7. Controls
      a. Manual movement controls
      b. Feed rate selector and feed engage
      c. Rapid traverse
      d. Spindle controls
      e. Locks
    8. Swivel housing on saddle of Universal Milling Machine
II. Discuss the Types of Spindles, Arbors, and Adaptors Used on the Horizontal Milling Machine
  A. Mill Spindle Tapers
  B. Arbors
    1. Style A
    2. Style B
    3. Style C
    4. Spacing Collars
    5. Bearing Collars
    6. Support Bearings

- C. Adapters
- D. Collets
- E. Quick-Change Systems

III. List Several Common Work Holding Methods
- A. Direct Table Mounts
  - 1. Clamp supports
  - 2. Screw jacks
- B. Mill Vises
- C. Miscellaneous Holders
  - 1. Rotary table
  - 2. Dividing head
  - 3. V-Blocks
  - 4. Specially made milling fixtures

IV. Use Plain Milling Cutters
- A. Roughing
- B. Squaring
- C. Milling Endpieces

V. Use Side Milling Cutters
- A. Setup
- B. Positioning the Cutter
- C. Making the Cut
  - 1. Keyseats
  - 2. Straddle and Gang Milling
- D. Helical Side Milling Cutters
  - 1. Uses
  - 2. Handedness

VI. Use Face Milling Cutters
- A. Composition and Inserts
- B. Uses
- C. Lead Angles and Rake Angles
- D. Wiper Flats

CNC-F6-LE
Operate Horizontal Milling Machines
Attachment 2: MASTER Laboratory Exercise

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1. The instructor will demonstrate:
   a. How to use plain milling cutters;
   b. How to use side milling cutters;
   c. How to use face milling cutters;
   d. How to recognize and utilize various spindles, arbors, and adaptors; and,
   e. How to set up workpieces appropriately.

2. Students will:
   a. Use plain milling cutters;
   b. Use side milling cutters;
   c. Use face milling cutters;
   d. Recognize and utilize various spindles, arbors, and adaptors; and,
   e. Set up workpieces appropriately.

CNC-F6-LA
Operate Horizontal Milling Machines
Attachment 3: MASTER Laboratory Aid

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

Name____________________________ Date_______________

CNC-F6
Operate Horizontal Milling Machines
Self-Assessment

Circle the letter preceding the correct answer.

1. What is one of the purposes of the overarm?
   A. To hold the quill
   B. To reduce vibration
   C. To perform regressing cuts
   D. All of the above answers are valid.
   E. None of the above answers are correct.

2. A bed-type milling machine has a fixed ___ and an adjustable ___.
   A. Bed. . .spindle
   B. Bed. . .quill
   C. Spindle. . .table
   D. Spindle. . .bed
   E. None of the above items is correct.

3. Horizontal milling machines have attachments that emulate the functions of:
   A. Vertical milling machines.
   B. Spiral mills.
   C. Angular swivels.
   D. All of the above answers are valid.
   E. None of the above answers is correct.

4. Which of the following is *not* a hazard of the horizontal milling machine?
   A. Loose hair being wrapped around a smooth, spinning shaft
   B. Jewelry causing electrical sparks or shorts
   C. Long sleeves getting caught in rotating machinery
   D. All of the above are hazards of the horizontal milling machine.
   E. None of the above answers is correct.

5. Technician A says that the horizontal milling machine has locks on the table, saddle, and knee. Technician B says that, while milling, all locks should be engaged except that of the moving axis. Who is correct?
   A. Technician A only
   B. Technician B only
   C. Both technicians are correct.
   D. Neither technician is correct.

6. The universal milling machine has a ___ and is specially adapted to cut ___.
A. 45° table swivel. . .helical grooves
B. 45° table swivel. . .circular runs
C. 90° table swivel. . .helical grooves
D. 90° table swivel. . .circular runs
E. None of the above answers is correct.

7. Technician A says that the style A arbor is used only on small milling machines. Technician B says that the style B arbor is used to obtain a rigid setup for heavy-duty operations. Who is correct?
A. Technician A only
B. Technician B only
C. Both technicians are correct.
D. Neither technician is correct.

8. A stub arbor is:
A. Also known as a shell end mill arbor.
B. Sometimes called a style C arbor.
C. Used to hold shell end milling cutters.
D. All of the above answers are correct.
E. None of the above answers is correct.

9. Technician A says that the direction of rotation of a milling cutter determines whether it is right- or left-handed. Technician B says that counter-clockwise rotation determines right-handed cutting. Who is correct?
A. Technician A only
B. Technician B only
C. Both technicians are correct.
D. Neither technician is correct.

10. If the workpiece is *narrower* than the cutter itself, the technician should use a:
A. Shell end milling cutter.
B. Side milling cutter.
C. Plain arbor-driven cutter.
D. Any of the above cutters are appropriate.
E. None of the above answers is correct.

11. Steps and grooves are generally cut with a:
A. Shell end milling cutter.
B. Side milling cutter.
C. Plain arbor-driven cutter.
D. Any of the above cutters are appropriate.
E. None of the above answers is correct.

12. What is the advantage of a staggered-tooth side milling cutter?
    A. Reduced chatter
    B. Better chip formation
    C. Higher feeds
    D. All of the above answers are correct.
    E. None of the above answers is correct.

13. Inserted-tooth carbide cutters usually have an adjustment width of:
    A. 0.060 inch.
    B. 0.060 centimeters.
    C. 0.060 millimeters.
    D. This is a trick question. Inserted-tooth carbide cutters are not adjustable.
    E. None of the above answers is correct.

14. When mounting the workpiece directly to the table, the clamp supports must be ___ the workpiece.
    A. Lower than
    B. The same height as
    C. Higher than
    D. It just doesn't matter.
    E. None of the above answers is correct.

15. Angular milling cutters are used for:
    A. V-notches.
    B. Dovetails.
    C. Serrations.
    D. All of the above are cut with angular milling cutters.
    E. None of the above answers is correct.

16. Very deep cuts are generally made with ___, due to their greater chip-carrying capacity.
    A. Side tooth metal slitting saws
    B. Staggered tooth metal slitting saws
    C. Half side milling cutters
    D. Inserted-tooth carbide cutters
    E. None of the above answers is correct.

17. How is a plain vise, bolted to the machine table, aligned?
    A. With two perpendicular slots on the underside of the vise
    B. With two parallel slots on the underside of the vise
    C. By the use of removable keys that fit into the table's T-slots
    D. By A combined with C
    E. By B combined with C

18. In normal toolroom work, a vise must be tightened by ___ whenever high stress is used in cutting.
   A. Pneumatic attachments
   B. Hydraulic attachments
   C. Striking the crank handle of the vise with a soft-faced mallet
   D. Striking the crank shaft of the vise with a ball-peen hammer
   E. None of the above answers is correct.

19. A swivel vise can be rotated ___ degrees vertically and ___ horizontally.
   A. 360 . . . 0
   B. 270 . . . 90
   C. 180 . . . 180
   D. 90 . . . 270
   E. 0 . . . 360

20. Generally speaking, a depth of cut of less than ___ will cause the cutter to *rub* rather than *cut*.
   A. .030 inch
   B. .015 inch
   C. .005 inch
   D. .001 inch
   E. None of the above answers is correct.

21. Most milling with carbide cutters is done dry. Why?
   A. An interrupted flow of cutting fluid will ruin the mill engine.
   B. An interrupted flow of cutting fluid will cause thermal cracking of the tool.
   C. Carbide cutters must be cooled strictly in air to maintain their cutting edges.
   D. The premise of this questions is flawed. Carbide cutters use cutting fluid just like other cutters.
   E. None of the above answers is correct.

22. Under normal conditions, when should the machinist choose climb milling for the horizontal milling machine?
   A. When the workpiece must be cut to extremely tight tolerance
   B. When the cutter is beginning to dull
   C. When the tolerance of the workpiece is very loose
   D. Climb milling is not recommended under most conditions.
   E. None of the above answers is correct.

23. When gang milling, the cutter rpm is determined by the diameter of the ___ cutter in the gang.
A. Largest
B. Average
C. Smallest
D. Gang milling can only be done with cutters of equal diameters.
E. None of the above answers is correct.

24. High-speed face milling cutters are normally used with ___ rake angles.
A. Positive
B. Neutral or no
C. Negative
D. Large, regardless of the declinsion.
E. None of the above answers is correct.

25. When finishing, the machinist should use ___ wiper flat(s) with a maximum feed rate of ___ of the width of one wiper flat.
A. One . . . one-half
B. One . . . two-thirds
C. Two . . . one-half
D. Two . . . two-thirds
E. None of the above answers is correct.

CNC-F6
Operate Horizontal Milling Machines
Self-Assessment Answer Key

1. B
2. C
3. D
4. D
5. C
6. A
7. C
8. D
9. A
10. C
11. B
12. D
13. A
14. B
15. D
16. B
17. D
18. E
19. E
20. C
21. B
22. D
23. A
24. A
25. B

CNC-F7

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-F7

Subject: **Advanced CNC and CAM** **Time: 40 Hrs.**

Duty: **Perform Conventional Machining**
Task: Operate Metal Cutting Lathes

Objective(s):

Upon completion of this unit the student will be able to:
a. Identify major component parts of an engine lathe;
b. Properly set up and use lathe accessories required for basic lathe operation;
c. Determine correct speed and feed for a given metal;
d. Identify safety concerns relative to lathe operation;
e. Demonstrate set up and use of lathe centers;
f. Identify and use different types of lathe cutting tools;
g. Face, cut and turn stock to a specified tolerance;
h. Demonstrate method of drilling, boring and reaming a hole to obtain specified tolerance; and,
i Demonstrate setup and correct procedures to machine sixty-degree internal and external threads.

Instructional Materials:

MASTER Handout (CNC-F7-HO)
MASTER Laboratory Exercise (CNC-F7-LE)
MASTER Laboratory Aid (CNC-F7-LA)
MASTER Self-Assessment
2" aluminum stock for practice and evaluation
9 5/8" of 1" diameter CRS
Assortment of outside micrometers up to 3"
Depth gage
Dial calipers
Engine lathe
Hand tools
Side shield and face shield
Telescope gage
Tool grinder
Tool stock

References:

Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition, "Turning Machines"

NTMA Modules:

MA-I-26	"Engine Lathe: Introduction"
MA-I-28	". . .Care & Safety"
MA-I-30	". . .Type & Function"
MA-I-32	". . .Cutting Tools & Fluids"
MA-I-34	". . .Accessories & Work Holding Devices
MA-I-36	". . .Selecting Speeds & Feeds"
MA-I-38	". . .Facing, Turning & Boring
MA-I-40	". . .Drilling, Reaming & Taper Turning
MA-I-42	". . .Threading"
MA-I-44	". . .Auxiliary Tooling"

Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-A1 through CNC-A5 "Practice Safety"
CNC-B7 "Calculate Speeds and Feeds for Machining"
CNC-C1 through CNC-C10 "Interpret All Engineering Drawings and Control Documents"
CNC-E3 "Measure With Hand Held Instruments"
CNC-F1 "Prepare and Plan for Machining Operations"

Introduction:

The lathe is the single most important tool of the machinist. Of all the machines we make and use, only the lathe is capable of being used to replicate itself. While this aspect alone makes it unique in industry, the lathe is most extensively used to fabricate and duplicate cylindrical parts for other machines. Expertise in the lathe is *the* fundamental skill of a machinist.

Presentation Outline:

I. Discuss the Importance of the Lathe to the Machinist. Provide Classroom Handouts and Laboratory Worksheets to the Students.
II. Identify and Discuss Component Parts of the Engine Lathe
III. Discuss Lathe Safety
IV. Identify, Set Up, and Demonstrate Use of Lathe Accessories
    A. Cutting Fluids
    B. Follower and Steady Rest
    C. Compound Rest

    D. Mandrel
V. Discuss and Demonstrate How to Select the Correct Speed and Feed for Various Metals
    A. Steel
    B. Aluminum
    C. Brass
VI. Discuss and Demonstrate the Use of Lathe Centers
    A. Mounting
    B. Removing
    C. Aligning
VII. Discuss and Demonstrate Use of Cutting Tools
    A. Grinding a high speed toolbit
    B. Re-conditioning point of toolbits
    C. Types of cutting tools
VIII. Discuss and Demonstrate Turning Between Centers
    A. Why face out?
    B. Center drill
    C. Tailstock center
    D. The steady rest
    E. Using chucks
IX. Discuss and Demonstrate Methods of Drilling, Boring, and Reaming Using the Lathe
X. Discuss Threads, Threading, and Thread Applications
XI. Student Practice

Practical Application:

Students will make a light-weight ball-peen hammer and a gravity-feed center punch in the laboratory. These projects also constitute their performance demonstrations.

Evaluation and/or Verification:

Successful completion of this Technical Module will be based on the student's successful completion of the following components. The student shall:

1. Complete the Self-Assessment at the end of this module.
2. Successfully identify the parts of the lathe. The instructor will determine whether the student is ready to progress.
3. Demonstrate safe operation of the lathe.
4. Fabricate the hammer to the specified tolerances when given the drawing, detailed instructions, tools, equipment, and work stock.
5. Fabricate the punch to the specified tolerances when given the drawing, tools, equipment, and work stock.

Summary:

Review the main lesson points using the objectives as a guide. Hold class discussions and answer students' questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-F8) dealing with operating grinding/abrading machines.

CNC-F7-HO
Operate Metal Cutting Lathes
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

- a. Identify major component parts of an engine lathe;
- b. Properly set up and use lathe accessories required for basic lathe operation;
- c. Determine correct speed and feed for a given metal;
- d. Identify safety concerns relative to lathe operation;
- e. Demonstrate set up and use of lathe centers;
- f. Identify and use different types of lathe cutting tools;
- g. Face, cut and turn stock to a specified tolerance;
- h. Demonstrate method of drilling, boring and reaming a hole to obtain specified tolerance; and,
- i Demonstrate setup and correct procedures to machine sixty-degree internal and external threads.

Module Outline:

- I. Discuss the Importance of the Lathe to the Machinist. Provide Classroom Handouts and Laboratory Worksheets to the Students.
- II. Identify and Discuss Component Parts of the Engine Lathe
- III. Discuss Lathe Safety
- IV. Identify, Set Up, and Demonstrate Use of Lathe Accessories
  - A. Cutting Fluids
  - B. Follower and Steady Rest
  - C. Compound Rest
  - D. Mandrel
- V. Discuss and Demonstrate How to Select the Correct Speed and Feed for Various Metals
  - A. Steel
  - B. Aluminum
  - C. Brass
- VI. Discuss and Demonstrate the Use of Lathe Centers
  - A. Mounting
  - B. Removing
  - C. Aligning
- VII. Discuss and Demonstrate Use of Cutting Tools
  - A. Grinding a high speed toolbit
  - B. Re-conditioning point of toolbits
  - C. Types of cutting tools

VIII. Discuss and Demonstrate Turning Between Centers
  A. Why face out?
  B. Center drill
  C. Tailstock center
  D. The steady rest
  E. Using chucks
IX. Discuss and Demonstrate Methods of Drilling, Boring, and Reaming Using the Lathe
X. Discuss Threads, Threading, and Thread Applications
XI. Student Practice

CNC-F7-LE
Operate Metal Cutting Lathes
Attachment 2: MASTER Laboratory Exercise

I. The instructor will discuss and review the working drawings.

II. Students will practice safe work habits at all times.

III. Students will review the work prints at their work stations. (Be sure you understand *all aspects* of the working drawings before beginning the exercise.)

IV. Specific Procedures for This Exercise
  A. General Shop Rules
    1. Immediately put absorbent on all oil spills.
    2. Thoroughly clean the machine and the area around it when you are finished working at that station.
    3. Return all assigned tools to their proper places.
  B. General Lathe Rules
    1. Never attempt to stop a turning chuck.
    2. Never try to measure moving parts. Wait until they stop.
    3. The chuck should always turn *toward* you when it is in the FORWARD position.
    4. The tool steel should not stick out more than one-half inch from the toolholder.

V. Fabrication of the Ball-Peen Hammer—Handle Form
  A. Cut off at least 9 5/8 inches of 1 inch diameter CRS (cutting speed 100); wipe it clean and deburr it on the pedestal grinder using the coarse wheel.
  B. Check the following before starting the lathe.
    1. The spindle should be free.
    2. The carriage should be free.
    3. The cross feed should be free.
    4. The chuck wrench must be removed from the chuck.
  C. Face the stock to a length of 9 ½ inches.
  D. Center drill each end.
  E. Put the chuck on 2 inches of the stock and support the workpiece with the tailstock and the live center.
  F. Mark 6 inches from the end of the workpiece with the turning tool.
  G. Turn this 6 inches down to 0.800 inch.
    1. Touch the rotating workpiece with the tool and set the crossfeed dial to zero (0).

    2. Take four cuts of 0.050 at a feed of 0.004.
    3. On the fourth cut, stop the feed after 3/8 inch and check for the proper diameter. Adjust as necessary.

H. Mark 5/8 inch from the end of the workpiece.
I. Turn this 5/8 inch down to 0.550.
J. File all edges using the file handle in the left hand.
K. File a straight flat along the turned surface in line with the #1 chuck jaw.
L. Unchuck the workpiece. *Remove the chuck wrench.*
M. Remove the workpiece and place 2 inches of the **turned** end into the chuck, placing the file flat under the #1 chuck jaw. *Remove the chuck wrench.*
N. Adjust the tailstock pressure so that the live center turns with the workpiece.
O. Mark 4 5/8 inches from the end and turn to 0.700 OD ± 0.005.
P. Mark 4 3/16 inches from the end and turn to 0.600 OD ± 0.005.
Q. Mark 3 3/8 inches from the end and turn to 0.425 OD ± 0.005.
R. Set the lathe to the proper feed and speed for finishing and finish the three ODs from O, P, & Q to the print dimensions.
S. Break all sharp edges with a file.
T. Reverse the work. Chuck on the 0.375 OD. *Remove the chuck wrench.* Protect the finished ODs with an appropriate buffer.
U. Finish turning the handle to the print dimensions.

VI. Fabrication of the Ball-Peen Hammer—Threads and the Head

A. Cut off at least 4 1/8 inches of 1 inch diameter 4140, painted red (cutting speed 60). Clean and deburr as before.
B. Face one end.
C. Mark 5/8 inch from the end and turn to 0.500 + 0.000 -0.010.
D. File a flat for the #1 chuck jaw, reverse the work and repeat B and C for the other end of the workpiece.
E. Get the parting tool for the respective machine.
    1. Check the parting tool for sharpness.
    2. Mount the parting tool in the tool post.
    3. Make sure that the parting tool is square to the workpiece and on center.
    4. Feed slowly, using both hands, at 100 RPM.

F. Cut a neck for the threads to run on at each end of the head and on one end of the handle.
    1. Touch the parting tool to the workpiece and zero the cross slide.
    2. Feed in the double depth of the thread plus 0.010.

G. Thread both ends of the head to ½-20-NF. Test the threads with a test nut. *Do not proceed to H without instructor approval.*
H. Thread one end of the handle to ½-20-NF.

I. Either of two common methods of threading may be used. Check with the instructor before proceeding.
   1. Die and Pad
      a. Fix the handle on the large end.
      b. Using the die and the flat crotch pad, thread the small end of the handle to 3/8-24-NF.
   2. Threading Tool—thread to 3/8-24-NF.
J. Chuck onto the practice threads of the head and support the workpiece with the tailstock and live center.
K. Center drill the end of the head.
L. Mark 1 7/8 inches from the shoulder and turn to 0.875 ± 0.003. Make sure that the top tolerance is used to allow for filing and polishing.
M. Mark the #1 jaw, reverse the workpiece and center drill the other end.
N. From the 0.875 OD, turn the workpiece down to 0.750 ± 0.003.
O. Using the threading tool, mark the workpiece
   1. 13/16 inch *in from* the 0.875 OD.
   2. 3/8 inch in from the first mark.
   3. 5/8 inch in from the second mark.
   4. 3/8 inch in from the third mark.
P. Under cut the 3/8 inch spaces to 9/16 inch OD ± 1/64. Use a round nose tool, set the RPM to 100, and feed by hand. Make the last cut slowly to leave the cut smooth.
Q. Turn off the practice threads. Protect the finish in the chuck with an appropriate buffer.
R. Crown face the head end and free-hand form the ball peen.
S. Check all dimensions against the drawing for accuracy.

VII. Fabrication of the Ball-Peen Hammer — Knurling
   A. Chuck the handle at the 0.550 diameter (with proper buffers) and support the 0.500 diameter end with a well-lubricated dead center.
   B. Carefully mark where the knurl will be made.
   C. Set a medium knurling tool square to the workpiece and on center.
   D. Set the lathe to the proper feed and speed.
   E. Knurl the handle, using plenty of lubricants. Be sure that the pattern is correct *before* knurling the whole handle.
   F. Knurl the 1/4 inch cap screw. If a correct pattern is not obtained, knurl the entire handle grip and turn off the poorly-executed end.

VIII. Fabrication of the Ball-Peen Hammer — Completing the Handle
   A. Chuck on the knurl (buffer correctly).
   B. *While maintaining the tolerances,* file and polish each diameter of the handle separately.
   C. Clean the lathe especially well after polishing.

D. Move to the work bench. Place the handle in a vise (buffer the knurl) and saw off the end for the screw with a hacksaw.

E. Face the handle to length and drill and tap the storage hole as required.

F. Clean out the hole and install the screw. (A paper gasket may help prevent over-tightening.)

G. Face the screw to length and break the sharp edge. The handle is now complete.

IX. Fabrication of the Ball-Peen Hammer — Completing the Head

A. Lay out, center punch, and drill the head to the proper depth. Use the drill jig designed for this operation.

B. Tap the bore using a plug and bottom tap. Be sure the taps are started straight.

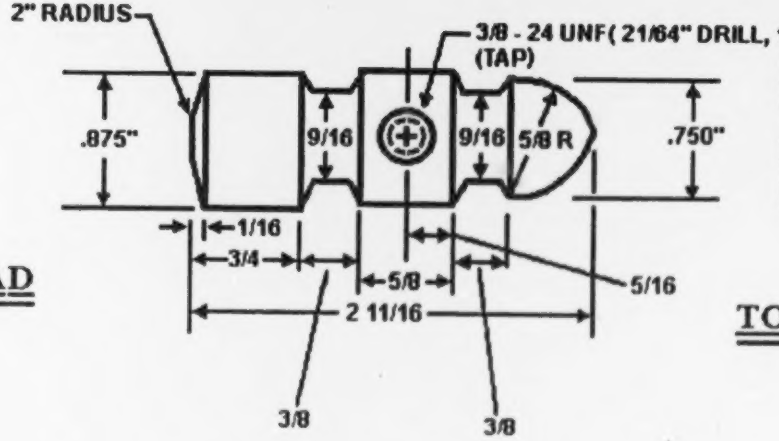
C. Polish the hammer head and clean the work area.

D. Heat the face of the hammer and the ball peen to cherry red; quench them in oil. Re-polish the head.

E. Heat the face of the hammer and the ball peen to straw color; quench them in oil. Re-polish the head.

X. Turn in the hammer and blueprints to the instructor for evaluation. You will know how well you have done by whether the hammer parts all actually fit together well and whether they are within tolerances.

XI. Once you have obtained the instructor's approval, you are ready to begin construction of the gravity-fed center punch. For that exercise, you will **not** be given linear instructions. You must use your own judgement on how and when to do what, following the blueprints. Remember to stay within tolerances, to keep your work area clean, and keep your chuck key in your hand or in your tool kit *at all times and in all circumstances.* Good Luck!


2" RADIUS
3/8 - 24 UNF(21/64" DRILL, 1/2" DEEP)
(TAP)
.875"
9/16
9/16
5/8 R
.750"
1/16
3/4
5/8
5/16
2 11/16
3/8
3/8

HEAD

HAMMER GRADE: ____________

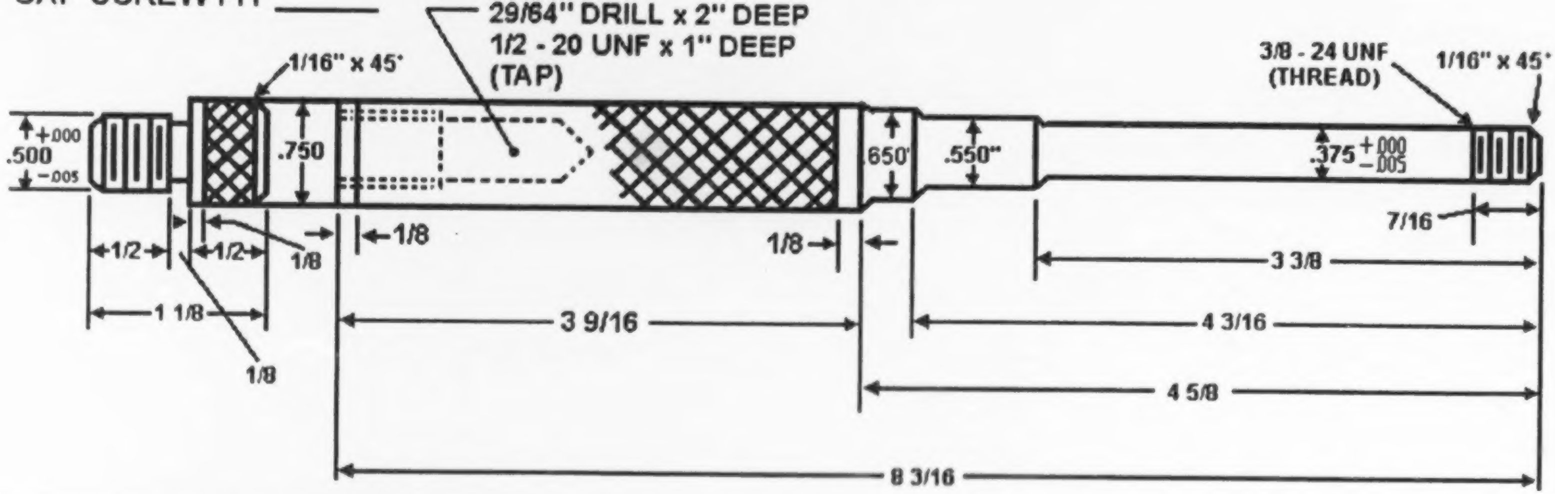
THREAD SQUARENESS: ____________

DIMENSIONS MISSED: ____________

SURFACE FINISH: ____________

TOLERANCES: FRACTIONS ± 1/64"
DECIMALS ± .005"

CAP SCREW FIT ______

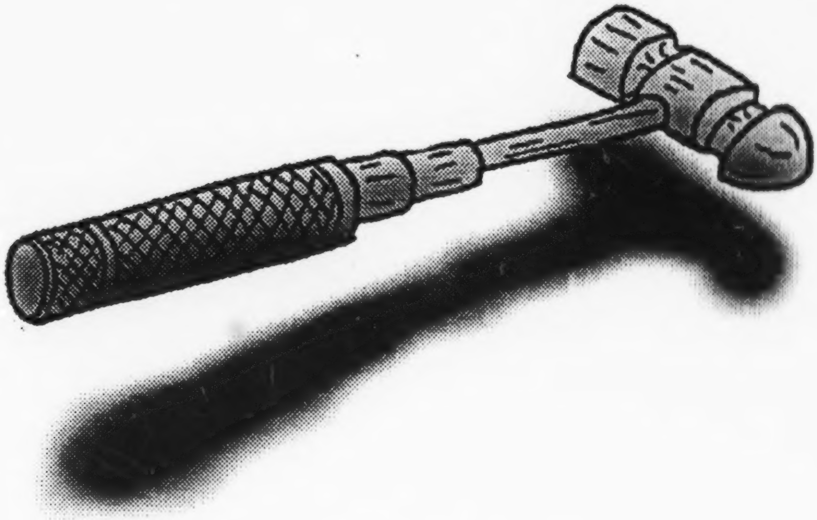

29/64" DRILL x 2" DEEP
1/2 - 20 UNF x 1" DEEP
(TAP)
1/16" x 45°
3/8 - 24 UNF
(THREAD)
1/16" x 45°
.500 +.000 -.005
.750
.650"
.550"
.375 +.000 -.005
1/2
1/2
1/8
1/8
1/8
1/8
1 1/8
1/8
7/16
3 3/8
3 9/16
4 3/16
4 5/8
8 3/16

MATERIAL

HEAD 4140 - HANDLE - C.R.S. 12 L 14

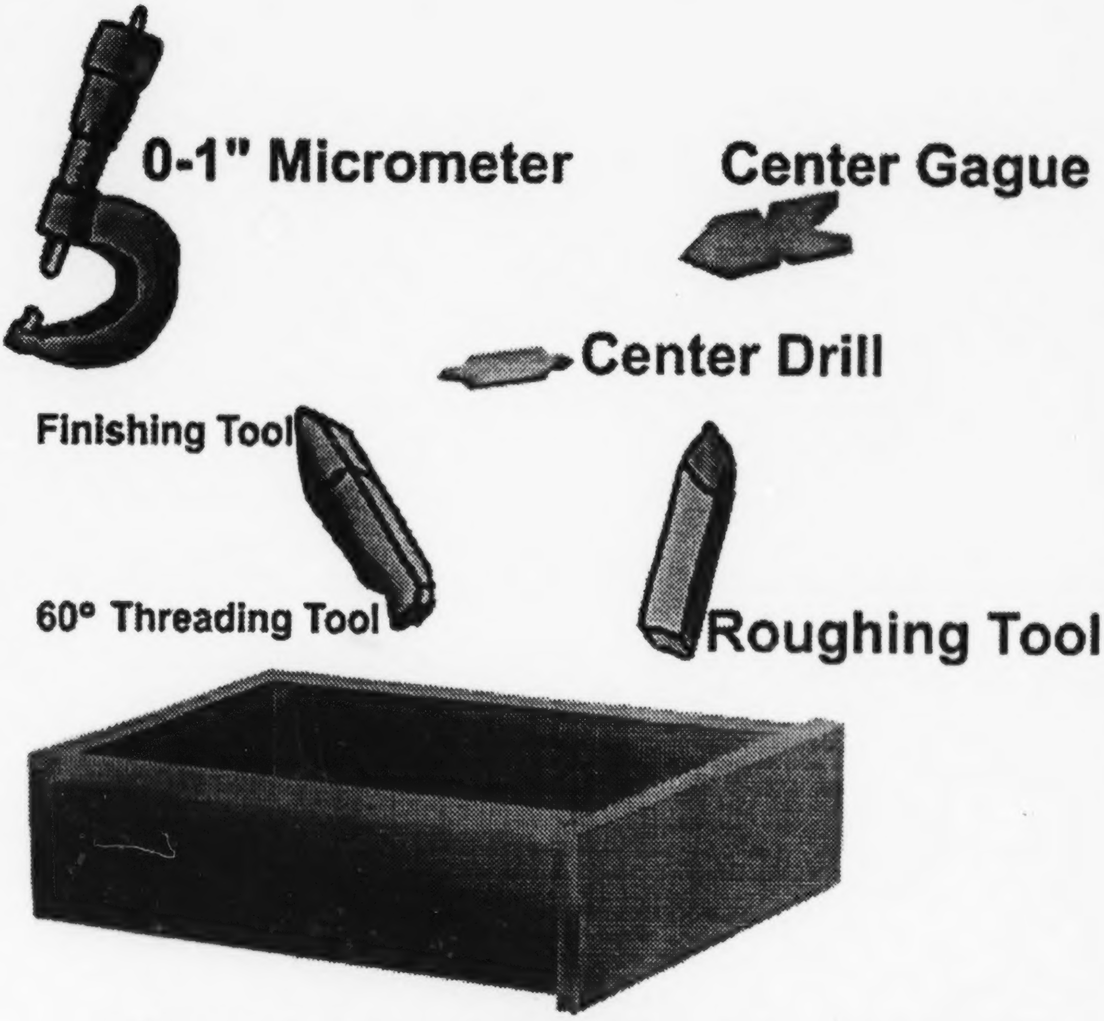
HANDLE

BALL PEEN HAMMER



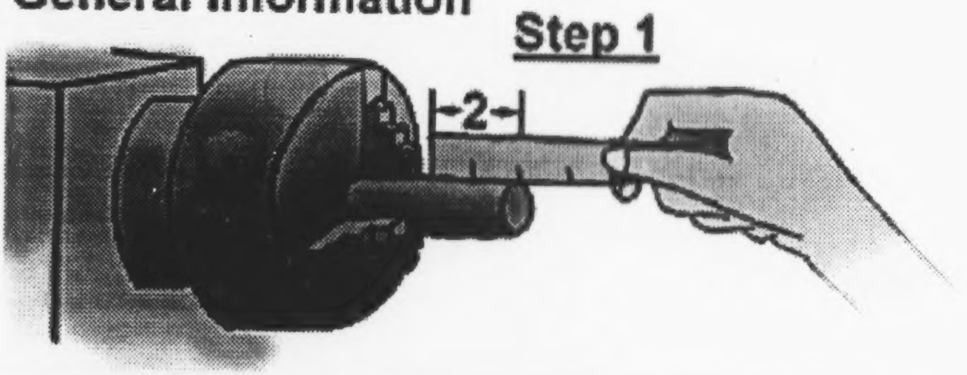
Objectives:

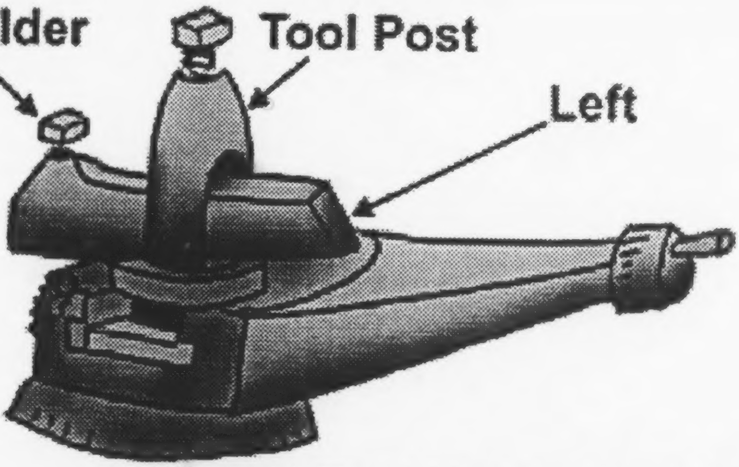
1. Become accquainted with work done in a machine shop.
2. Practice Engine Lathe Operation.
3. Observe the need for careful measuring.
4. See first hand the need for shop safety.


0-1" Micrometer
Center Gague
Center Drill
Finishing Tool
60° Threading Tool
Roughing Tool

These tools should be in your box.

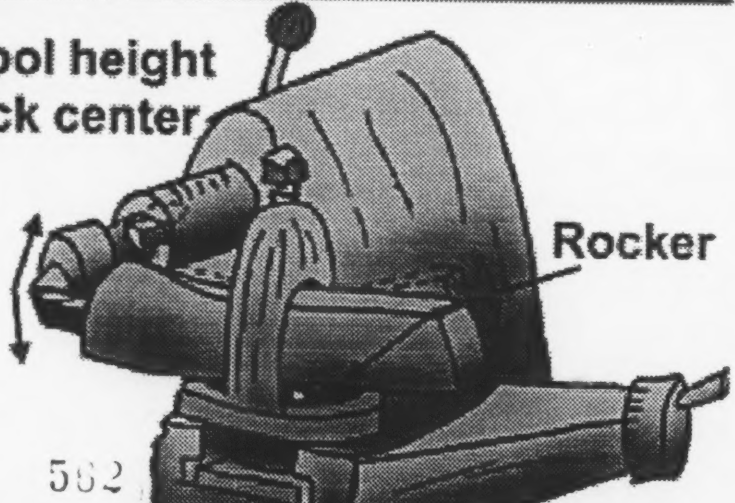
General Information

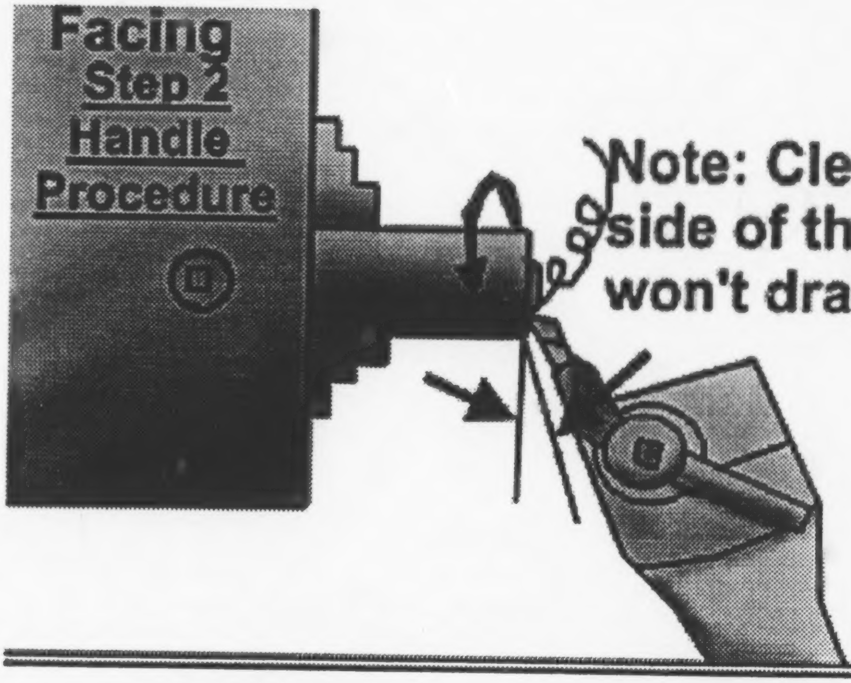



Tool Holder
Tool Post
Left

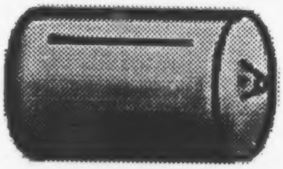
Mount Tool Holder to extreme left.

Setting cutting tool height
Using the tailstock center
as a guide.

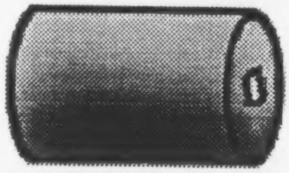



Facing
Step 2
Handle
Procedure

Note: Clearance so side of the tool won't drag on work.

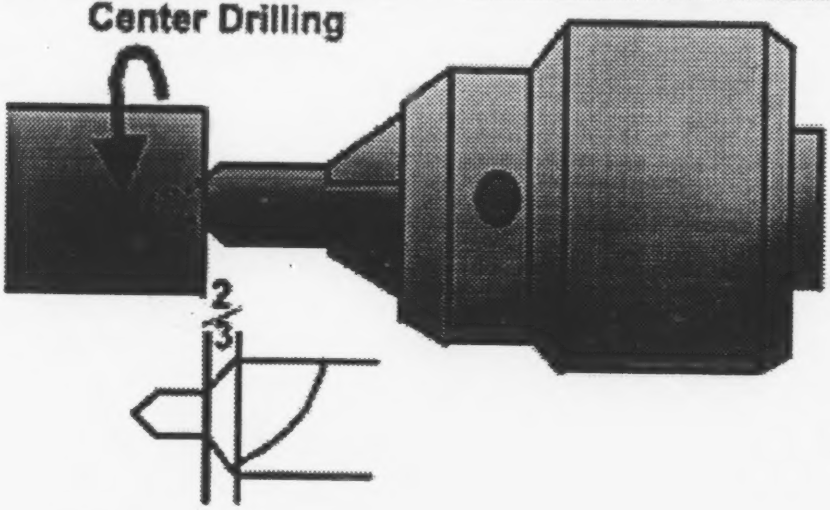


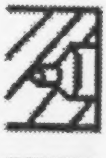
Point, Tool too Low.



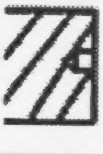
Rough, Tool too High.

Center Drilling

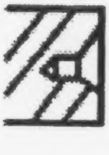




Too Deep

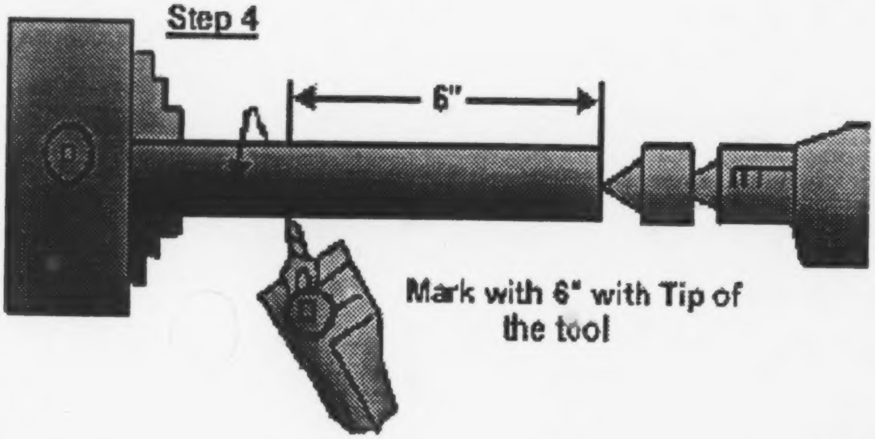


Too Shallow

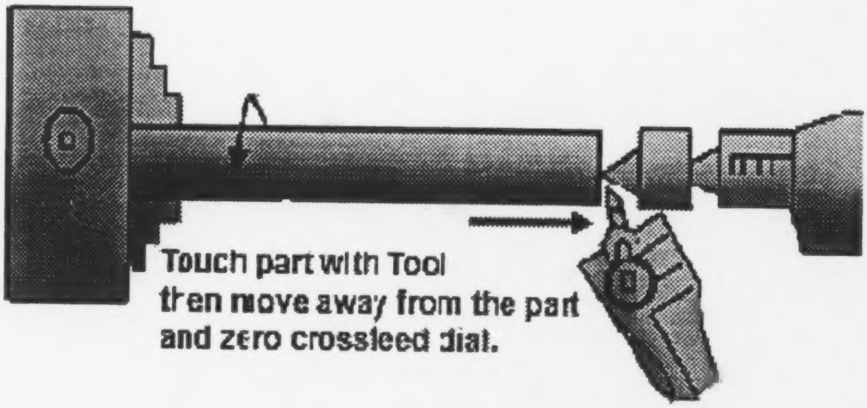


Correct

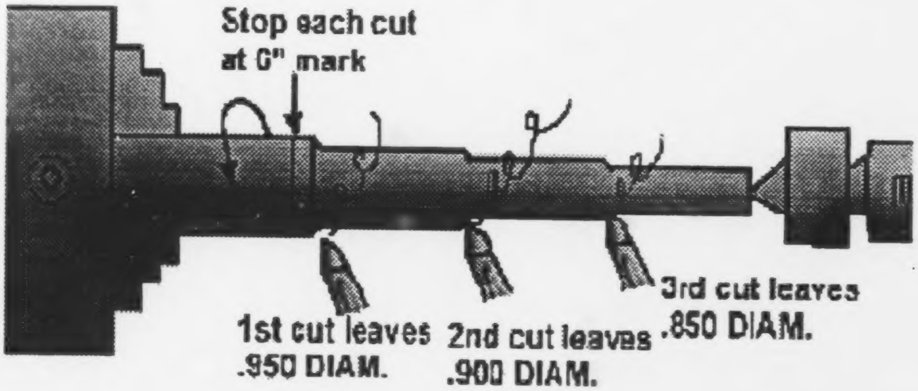
Step 4



Mark with 6" with Tip of the tool


Touch part with Tool then move away from the part and zero crossfeed dial.

STEP 5

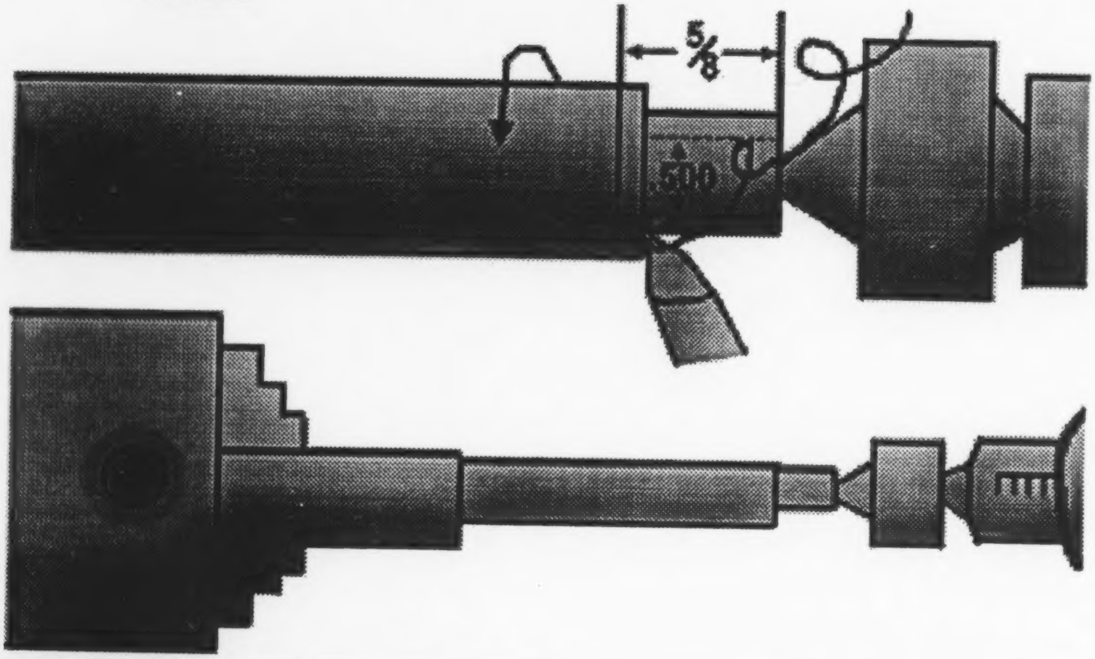

Stop each cut at 6" mark

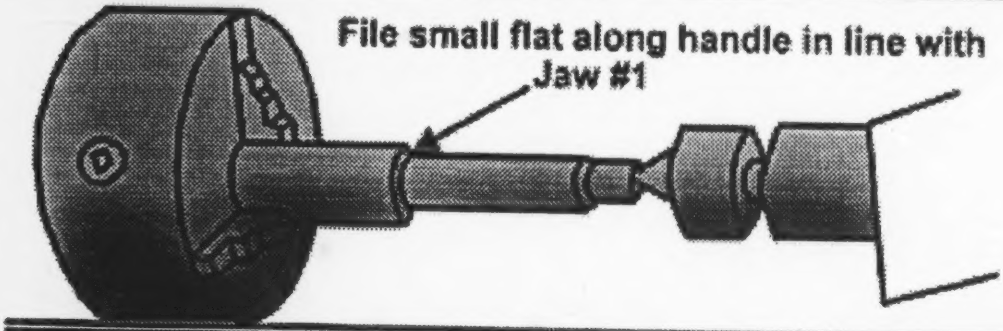
1st cut leaves .950 DIAM.

2nd cut leaves .900 DIAM.

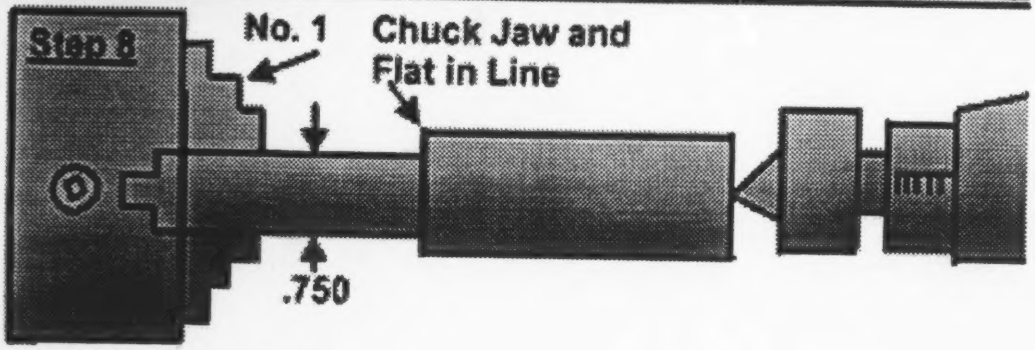
3rd cut leaves .850 DIAM.

Step 6

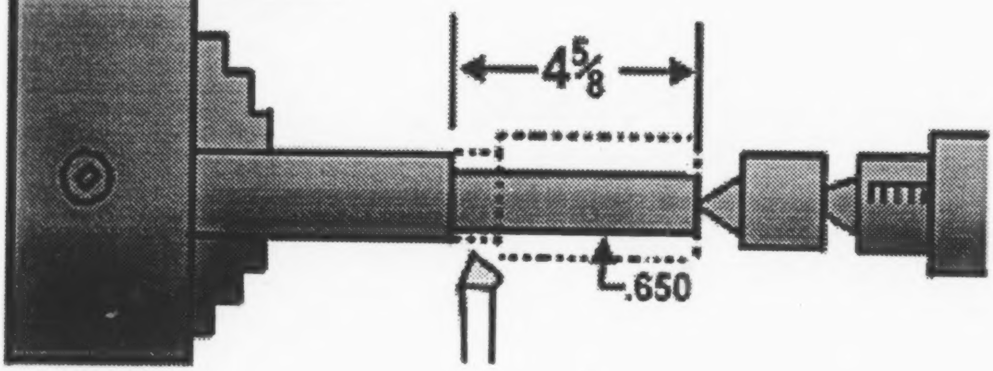

5/8
.500


File small flat along handle in line with Jaw #1

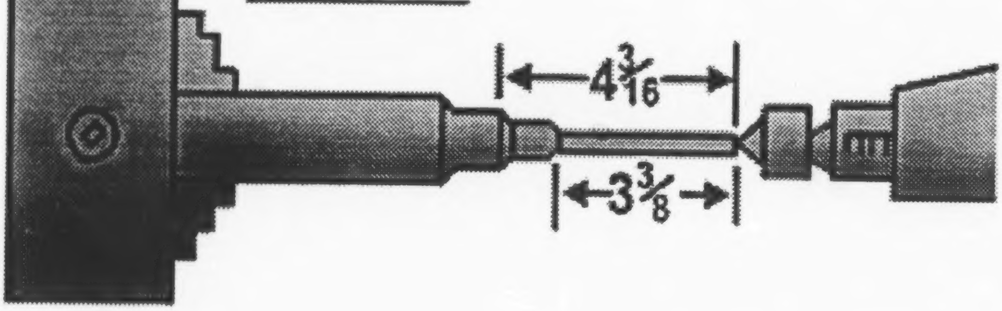
Step 8

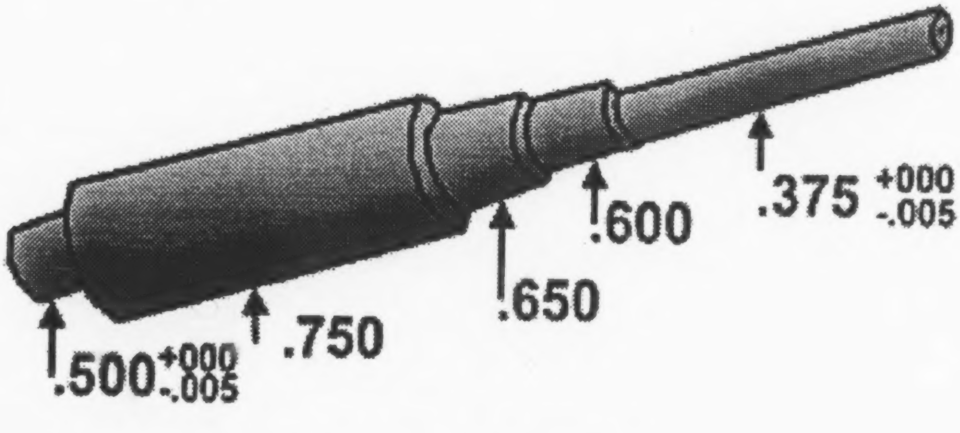

No. 1
Chuck Jaw and Flat in Line
.750

STEP 9

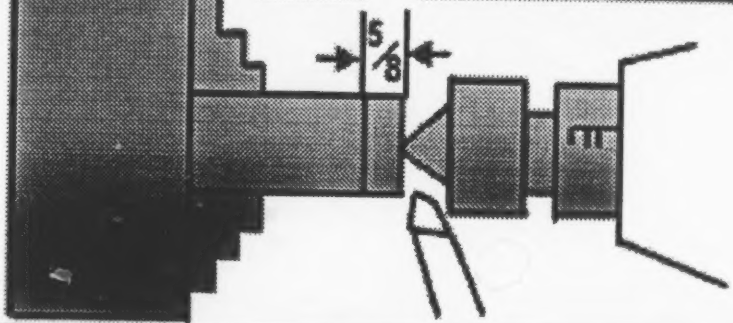


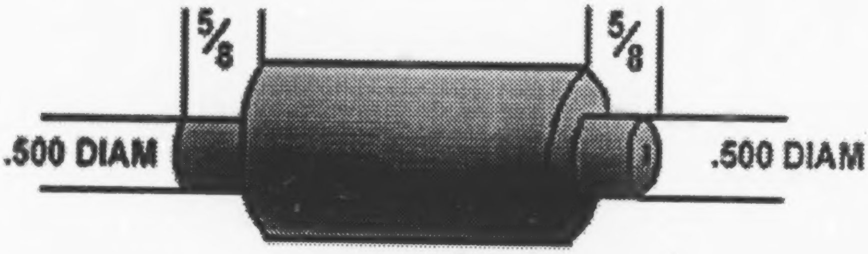
Steps 10 + 11

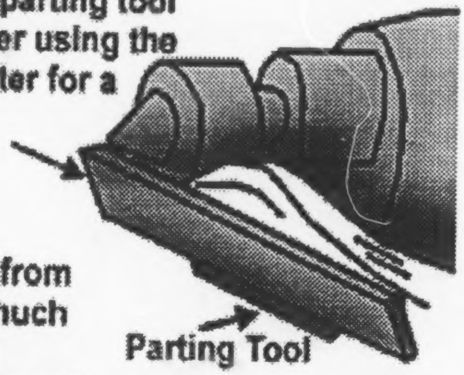



.375 +000 -.005
.600
.650
.750
.500 +000 -.005

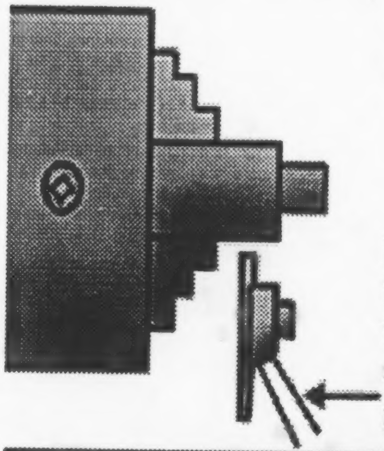
STEP 3 HAMMER HEAD PROCEDURE



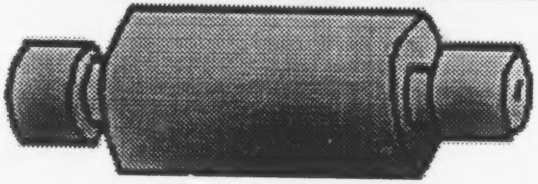

5/8
5/8
.500 DIAM
.500 DIAM


Parting Tool

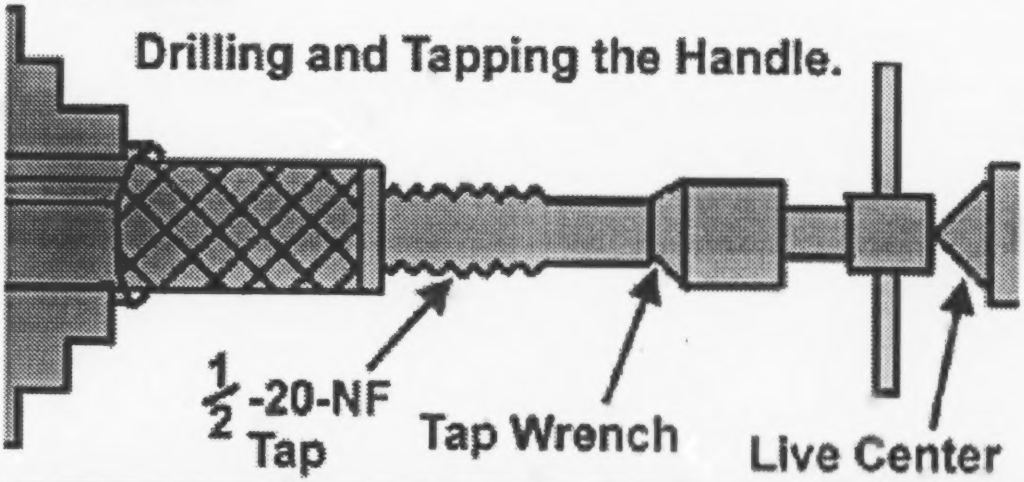
Setting parting tool on center using the live center for a gague.



Measure from face of chuch to check squareness of parting tool.



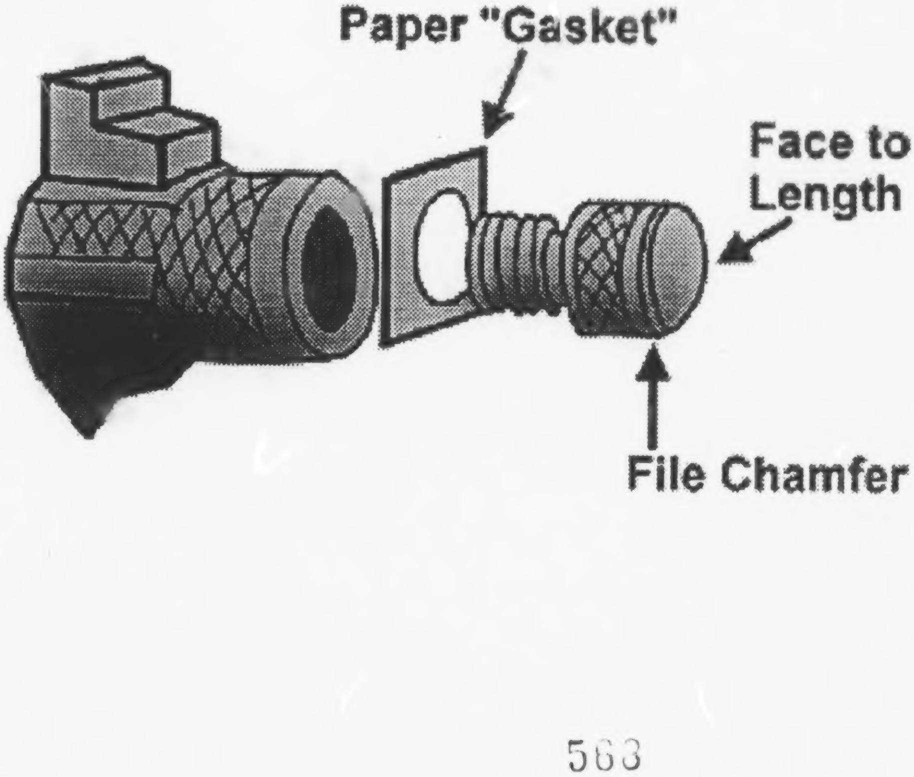
STEP 4



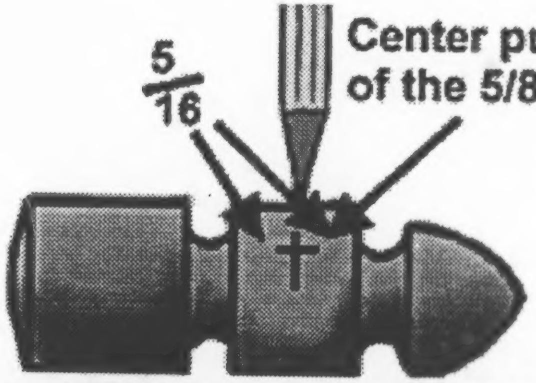
Drilling and Tapping the Handle.

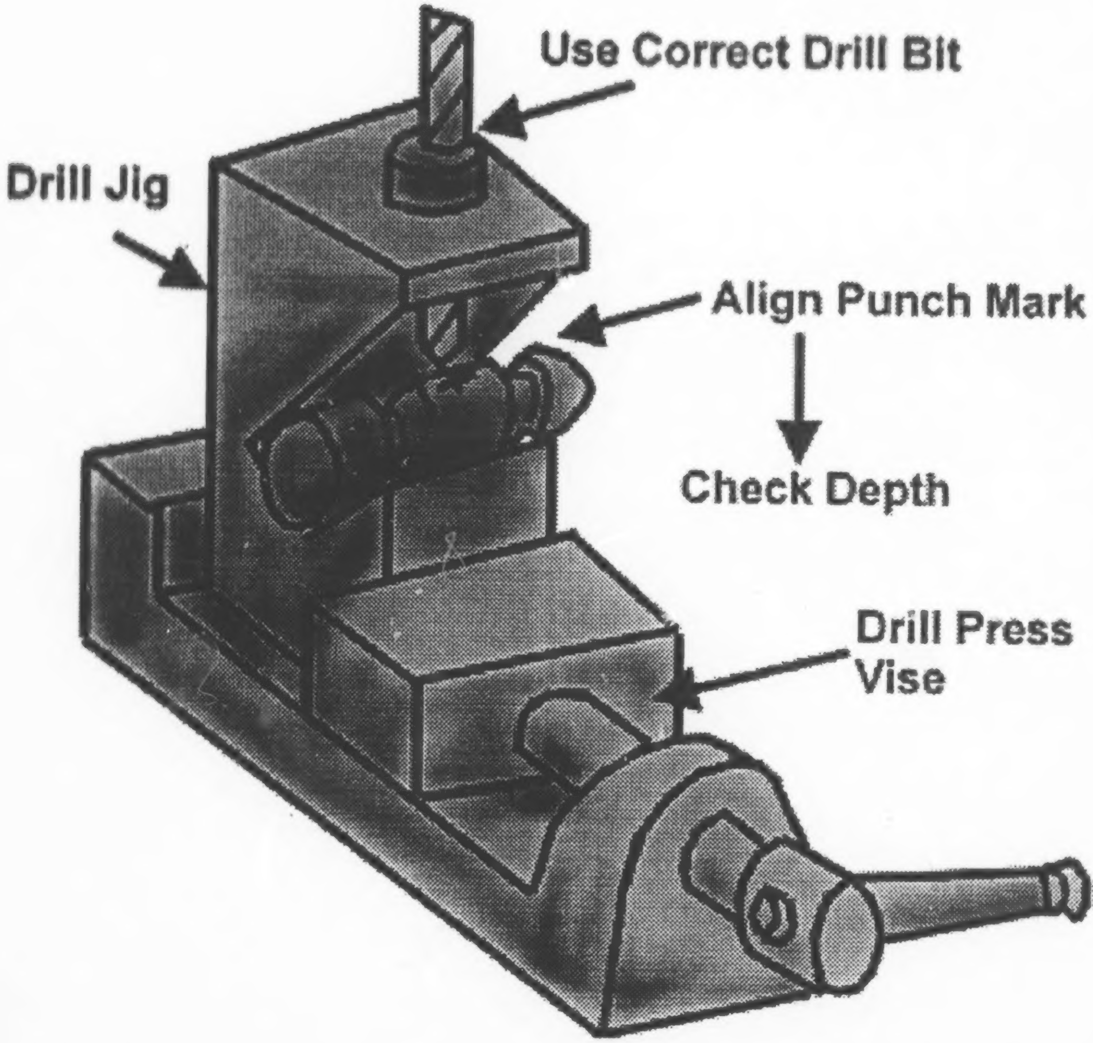
1/2-20-NF Tap
Tap Wrench
Live Center

STEPS 5+6



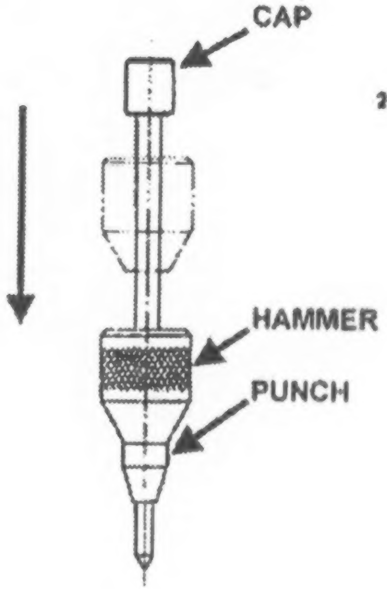
Paper "Gasket"
Face to Length
File Chamfer

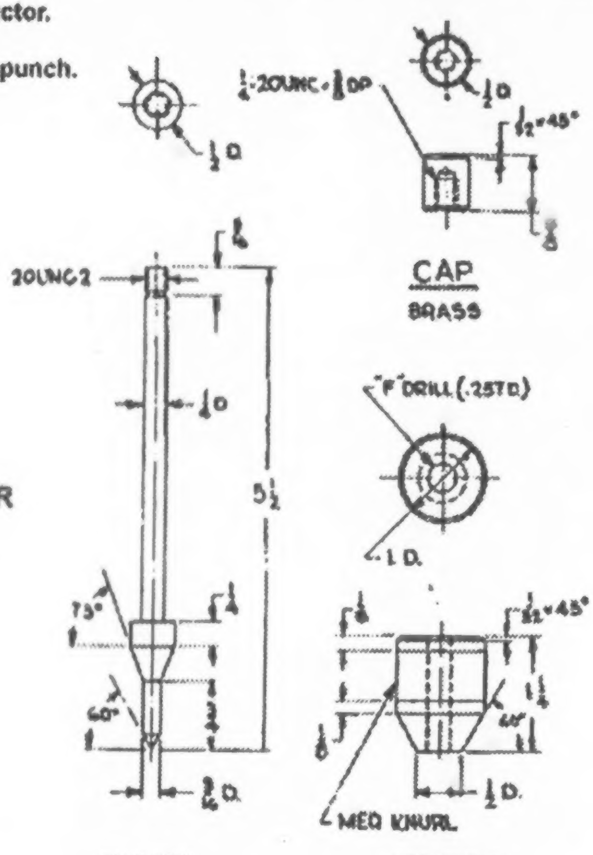

5/16
Center punch in the Center of the 5/8" wide section.


Use Correct Drill Bit
Drill Jig
Align Punch Mark
Check Depth
Drill Press Vise

1. Material: As noted.
2. Finish: Accepted machine shop practice
   little or no filling.
3. Tolerances: As indicated by your instructor.
4. Break all sharp edges.
5. Heat Treat only the point section of the punch.

GRAVITY CENTER PUNCH

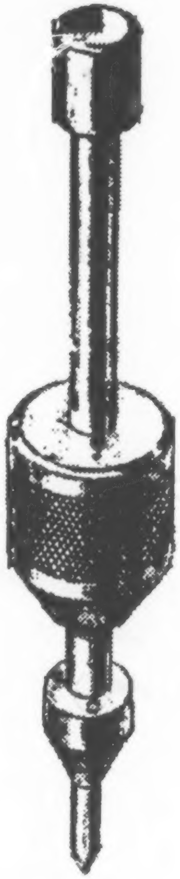

CAP
HAMMER
PUNCH


1/2 D
1/4-20UNC-3/8 DP
1/2 D
1/32×45°
3/8
1/8
20UNC2
1/4 D
5 1/2
75°
1/4
60°
3/4
3/16 D
"F" DRILL (.257 D)
1 D
1/8
1/32×45°
1 1/4
40°
3/8
1/2 D
MED KNURL

CAP
BRASS

PUNCH
DRILL ROD - HEAT TREAT

HAMMER
C.R.S.



Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

Name______________________ Date______________

CNC-F7
Operate Metal Cutting Lathes
Self-Assessment

Circle the letter preceding the most correct answer.

1. Machinist A says that technicians should keep their hands on their chuck wrenches "from the bench back to the bench." Machinist B says that the lathe is capable of turning thousands of times per minute. Who is correct?
   A. Machinist A only
   B. Machinist B only
   C. Both technicians are correct.
   D. Neither technician is correct.

2. Before starting the lathe, the machinist should ensure that the ___ is free (not locked).
   A. Spindle
   B. Carriage
   C. Crossfeed
   D. All of the above should be free before starting the lathe.
   E. None of the above answers is correct.

3. The chuck is driven by the:
   A. Spindle foot.
   B. Spindle nose.
   C. Saddle.
   D. Carriage.
   E. None of the above answers is correct.

4. Machinist A says that the half-nut (split-nut) lever should only be used to cut left-handed threads. Machinist B says that the half-nut lever is never used for general feeds. Who is correct?
   A. Machinist A only
   B. Machinist B only
   C. Both technicians are correct.
   D. Neither technician is correct.

5. Machinist A says that off-set toolholders are used for general machining on lathes. Machinist B says that straight-shank toolholders are used for machining close to the chuck or the tailstock to avoid interference from the tool post. Who is correct?
   A. Machinist A only
   B. Machinist B only
   C. Both technicians are correct.
   D. Neither technician is correct.

6. What is SCEA and why is it important?
   A. SCEA is the Side Cutting Edge Angle. If the SCEA is too large for the application, the tool may chatter.
   B. SCEA is the Side Cutting Edge Angle. If the SCEA is too large for the application, the tool will not cut.
   C. SCEA is the Spin-Chatter Elimination Attachment. If the SCEA is not attached, the lathe will not rotate uniformly and will chatter.
   D. SCEA is the Spinning Cleaning Enhancement Attachment. The SCEA makes the spindle, the toolholders, and the operator self-cleaning.
   E. None of the above answers is correct.

7. The ___ directs the chip flow toward the operator.
   A. Back rake
   B. Side rake
   C. Side relief angle
   D. No part of the lathe is designed to direct chip flow *toward* the operator.
   E. None of the above answers is correct.

8. Machinist A says that form tools have a tendency to chatter at higher speeds, so that cutting fluids and lower speeds are usually required. Machinist B says that form tools have special cutting faces that are used for external radii, threads, and dozens of other applications. Who is correct?
   A. Machinist A only
   B. Machinist B only
   C. Both technicians are correct.
   D. Neither technician is correct.

9. Cutoff or parting tools require a larger back rake for:
A. Tool steel.
B. Hard, non-ferrous metals.
C. Soft metals, such as aluminum.
D. The question is trivial; all cutoff tools have huge back rakes.
E. None of the above answers is correct.

10. What is the best solution to a tool which has been sharpened too many times?
A. Throw it away and replace it.
B. Lengthen the flank.
C. Grind off the old end and reform the cutting end.
D. Any of the above answers may be the solution.
E. None of the above answers is correct.

11. Which shape of chip is considered the safest?
A. C
B. 9
C. 8
D. D
E. None of the above answers is correct.

12. The back rake of high-speed steel tools is generally greater for ___ and virtually zero for ___.
A. Copper. . .alloy steels
B. Aluminum. . .bronze
C. Brass. . .nickel
D. Cast iron. . .brass (free cutting)
E. None of the above answers is correct.

13. When removing a chuck, the technician should *not* use a:
A. Monkey wrench.
B. Long steel bar.
C. Knockout bar.
D. All of the above may be used to remove the chuck.
E. None of the above answers is correct.

14. Machinist A says that the collet should never be tightened without a workpiece in its jaws. Machinist B says that it is important to clean the collets and adapters to ensure accuracy. Who is correct?
    A. Machinist A only
    B. Machinist B only
    C. Both technicians are correct.
    D. Neither technician is correct.

15. To ensure accuracy, the workpiece should not vary in size from the collet by more than:
    A. +.02 to -.03 inch.
    B. +.002 to -.003 inch.
    C. +.03 to -.02 inch.
    D. +.003 to -.002 inch.
    E. None of the above answers is correct.

16. If cast iron face plates are used at high speeds,
    A. The workpiece will warp.
    B. The lathe will jam.
    C. The T-slots will release the workpiece.
    D. This is a trick question. Cast iron face plates are routinely used at very high speeds.
    E. None of the above answers is correct.

17. The accuracy of centricity on a four jaw chuck depends mostly on:
    A. The condition of the chuck.
    B. The sharpness of the cutting tool.
    C. The ability of the machinist.
    D. All of the above affect the accuracy of centricity.
    E. None of the above answers is correct.

18. Machinist A says that the back gears must always be engaged with the spindle under power. Machinist B says that, on variable speed drives, they should not shift gears with the engine running and the clutch engaged. Who is correct?
    A. Machinist A only
    B. Machinist B only
    C. Both technicians are correct.
    D. Neither technician is correct.

19. When using the lathe, the diameter of the workpiece is reduced by ___ the amount to which the tool is set.
- A. Exactly
- B. Twice
- C. Thrice
- D. Half
- E. None of the above answers is correct.

20. When setting up for facing or center drilling, always tighten the jaws:
- A. Where the dial indicator contacts the work.
- B. Opposite the dial indicator's work-contact point.
- C. On the drive-side first.
- D. The tightening of the jaws does not affect the machining of the workpiece.
- E. None of the above answers is correct.

21. Machinist A says that cutoff or parting tools cannot be used when turning on centers without supports. Machinist B says that partially-completed threads cannot be checked if the workpiece is taken off the lathe. Who is correct?
- A. Machinist A only
- B. Machinist B only
- C. Both technicians are correct.
- D. Neither technician is correct.

22. Why is it that the center for the headstock is not often hardened?
- A. To prevent damage to the workpiece
- B. To prevent damage to the spindle dogs
- C. To facilitate its sharpening
- D. All of the above answers are correct.
- E. None of the above answers is correct.

23. Some micrometer collars on cross feed screws read:
- A. Single depth.
- B. Double depth.
- C. Directly.
- D. All of the above answers are correct.
- E. None of the above answers is correct.

24. Machinist A says that a workpiece may take several roughing cuts, depending on the size of the workpiece. Machinist B says that one or two finish cuts may be required, depending on the lathe. Who is correct?
   A. Machinist A only
   B. Machinist B only
   C. Both technicians are correct.
   D. Neither technician is correct.

25. Facing should not be done on pieces extending more than ___ times the ___ of the workpiece.
   A. Three. . .circumference
   B. Five. . .circumference
   C. Three. . .diameter
   D. Five. . .diameter
   E. None of the above answers is correct.

26. Machinist A says that the carriage must not be locked when taking facing cuts. Machinist B says that finer feeds, generally one-half to one-third that of longitudinal feeds, should be used when facing. Who is correct?
   A. Machinist A only
   B. Machinist B only
   C. Both technicians are correct.
   D. Neither technician is correct.

27. Machinist A says that center drilling requires a combination drill and countersink, usually between 1/8 and 3/4 inch body diameter. Machinist B says that such drills are classified by a numeric code from "000" to "8" which is stamped on the drill body. Who is correct?
   A. Machinist A only
   B. Machinist B only
   C. Both technicians are correct.
   D. Neither technician is correct.

28. If a taper is discovered while making a finish cut:
   A. It is easily repaired by re-aligning the tailstock.
   B. It is usually too late to save the workpiece.
   C. There is *nothing* that can save the workpiece.
   D. There is nothing wrong with a slight taper in any workpiece.
   E. None of the above answers is correct.

29. A test bar is a:
  A. Shaft without tapers and that is not eccentric.
  B. Hollow bar which fits over the stocks.
  C. A relaxing place to go after a major exam.
  D. None of the above answers is correct.

30. When center drilling, the machinist should:
  A. Frequently back the drill out to remove chips.
  B. Use cutting fluid.
  C. Maintain a slow drill feed.
  D. All of the above steps are necessary for center drilling.
  E. None of the above answers is correct.

31. When making facing cuts, the point of the tool should be set:
  A. Above center.
  B. At dead center.
  C. Below center.
  D. The initial position of the tool is immaterial.
  E. None of the above answers is correct.

32. When boring,
  A. Back rake is not usually used.
  B. There must be sufficient clearance for chip dispersal.
  C. The point of the boring tool must be on center.
  D. The must be enough end relief to prevent rubbing.
  E. All of the above answers are correct.

33. Machinist A says that facing cuts taken from the center of the workpiece will give better finishes, but are difficult to make. Machinist B says that facing cuts taken from the outside can be done with heavier cuts. Who is correct?
  A. Machinist A only
  B. Machinist B only
  C. Both Machinists A and B
  D. Neither Machinist A nor B

34. A blind hole:
- A. Does not pass completely through the workpiece.
- B. Is *not* threaded.
- C. Has been machined flat.
- D. Both A and C are correct.
- E. None of the above answers is correct.

35. Using the engine of the lathe to tap internally generally requires that:
- A. The spindle rotation be reversed.
- B. A spiral point tap be used.
- C. The hole run completely through the workpiece.
- D. All of the above answers are correct.
- E. None of the above answers is correct.

36. Knurls are:
- A. Usually formed with pressure.
- B. Used to improve the grip of the user of the tool.
- C. Used to enhance part grip in low-stress applications.
- D. All of the above answers are correct.
- E. None of the above answers is correct.

37. The term "threads per inch" means:
- A. The distance between two adjacent thread crests.
- B. The distance between two adjacent thread roots.
- C. Either 15 or 30, depending on whether the threads are coarse or fine.
- D. The thickness of the machinist's gloves.
- E. None of the above answers is correct.

38. The term "pitch" means:
- A. The distance between two adjacent thread crests.
- B. The distance between two adjacent thread roots.
- C. Either 15° or 30°, depending on whether the threads are coarse or fine.
- D. The angle of thread inclination.
- E. None of the above answers is correct.

39. The term "basic thread height (or depth)" means:
   A. The difference between the major and minor diameters of the screw.
   B. The difference between the original diameter of the workpiece and the finished diameter of the screw.
   C. One-half the major diameter of the finished screw.
   D. One-half the major diameter of the rough screw.
   E. None of the above answers is correct.

40. The angle of the threads in both the older American National and the newer American Standard for Unified threads is:
   A. 30°.
   B. 45°.
   C. 60°.
   D. 75°.
   E. None of the above answers is correct.

41. The proper rake angle for cutting threads with a cross slide is:
   A. 0°.
   B. 5°.
   C. 10°.
   D. 29°.
   E. None of the above answers is correct.

42. Spindle speeds for threading are approximately ___ those of turning.
   A. Twice
   B. Equal to
   C. Half
   D. One quarter
   E. None of the above answers is correct.

43. When cutting internal threads, bellmouth can result from:
   A. Too little infeed.
   B. Too much infeed.
   C. Insufficient cutting oil.
   D. Any of the above can cause bellmouth.
   E. None of the above answers is correct.

44. To eliminate chatter marks on workpieces which extend more than four diameters beyond the chuck, the machinist should:
    A. Lower the spindle speed.
    B. Raise the spindle speed.
    C. Lighten the cut.
    D. Use a steady rest.
    E. None of the above answers is correct.

45. Expansion from heating of the workpiece may require that the machinist adjust the ___ of the steady rest.
    A. Lower jaws.
    B. Trailing jaw.
    C. Upper jaw.
    D. This question is inaccurate; all steady rests automatically compensate for workpiece expansion.
    E. None of the above answers is correct.

46. Steady rests should never be used on:
    A. Finished surfaces.
    B. First cuts.
    C. Rough surfaces.
    D. Both B and C are correct.
    E. None of the above answers is correct.

Questions 47-50 deal with the identification of screw types by their thread patterns. You will obtain the screws from your instructor; write your answers on the following lines.

47. ____

48. ____

49. ____

50. ____

CNC-F7
Operate Metal Cutting Lathes
Self-Assessment Answer Key

1. C
2. D
3. B
4. B
5. D
6. A
7. D
8. C
9. C
10. C
11. B
12. B
13. C
14. C
15. B
16. E
17. C
18. B
19. B
20. A
21. A
22. C
23. D
24. D
25. D
26. B
27. A
28. B
29. A
30. D
31. B
32. E
33. C
34. A
35. D
36. D
37. E
38. A
39. A
40. C
41. A
42. D
43. B
44. D
45. C
46. C
47. ____________
48. ____________
49. ____________
50. ____________

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-F8

Subject: **Advanced CNC and CAM** **Time: 40 Hrs.**

Duty: **Perform Conventional Machining**
Task: Operate Grinding/Abrasive Machines

Objective(s):

Upon completion of this unit the student will be able to:

a. Discuss the selection and identification of grinding wheels;
b. Inspect, mount, true, dress, and balance grinding wheels;
c. Discuss common problems and solutions in surface grinding;
d. Operate horizontal spindle reciprocating table surface grinders;
e. Operate ID and OD grinders;
f. Operate honing machines; and,
g. Operate lapping machines.

Instructional Materials:

MASTER Handout (CNC-F8-HO)
MASTER Laboratory Exercise (CNC-F8-LE)
MASTER Laboratory Aid (CNC-F8-LA)
MASTER Self-Assessment
Sample grinding wheels of different abrasives
Sample grinding wheels of different forms

References:

Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition
Instructor's Manual, Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition
Student Workbook, Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition
Workbook for Machining Fundamentals, John R. Walker, The Goodheart-Willcox Co., Inc. Publishers, Latest Edition

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Student Preparation:

Students should have previously completed the following Technical Modules:
CNC-A1 through CNC-A5 "Practice Safety"

CNC-B7	"Calculate Speeds and Feeds for Machining"
CNC-E3	"Measure With Hand Held Instruments"
CNC-F1	"Prepare and Plan for Machining Operations"

Introduction:

Throughout a machinist's career, he will encounter countless reasons to use grinders and other abrasive tools. Such reasons range from re-working cutting tools to forming difficult parts from certain metals.

Presentation Outline:

I. Discuss the Selection and Identification of Grinding Wheels
  A. Types of Common Abrasives
  B. Uses of Common Abrasives
  C. Coding System
  D. Types of Grinding Wheels
    1. Surface Grinders
    2. Cylindrical Grinders
II. Inspect, Mount, True, Dress, and Balance Grinding Wheels
III. Discuss Common Problems and Solutions in Surface Grinding
  A. Use and Selection of Grinding Fluids
  B. Surface Grinding is NOT Face Grinding
IV. Operate Horizontal Spindle Reciprocating Table Surface Grinders
V. Operate ID and OD Grinders
VI. Operate Honing Machines
VII. Operate Lapping Machines

Practical Application:

The student should complete the laboratory worksheet at the end of this module. The students will also be able to identify the best grinding wheel for a specific operation.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-G1) dealing with understanding CNC basics.

CNC-F8-HO
Operate Grinding/Abrasive Machines
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Discuss the selection and identification of grinding wheels;
b. Inspect, mount, true, dress, and balance grinding wheels;
c. Discuss common problems and solutions in surface grinding;
d. Operate horizontal spindle reciprocating table surface grinders;
e. Operate ID and OD grinders;
f. Operate honing machines; and,
g. Operate lapping machines.

Module Outline:

I. Discuss the Selection and Identification of Grinding Wheels
    A. Types of Common Abrasives
    B. Uses of Common Abrasives
    C. Coding System
    D. Types of Grinding Wheels
        1. Surface Grinders
        2. Cylindrical Grinders
II. Inspect, Mount, True, Dress, and Balance Grinding Wheels
III. Discuss Common Problems and Solutions in Surface Grinding
    A. Use and Selection of Grinding Fluids
    B. Surface Grinding is NOT Face Grinding
IV. Operate Horizontal Spindle Reciprocating Table Surface Grinders
V. Operate ID and OD Grinders
VI. Operate Honing Machines
VII. Operate Lapping Machines

CNC-F8-LE
Operate Grinding/Abrasive Machines
Attachment 2: MASTER Laboratory Exercise

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1. **Instructor will demonstrate how to setup and operate a surface grinder to a tolerance of .002 without endangering personnel of equipment.**

2. **Student will demonstrate how to setup and operate a surface grinder to a tolerance of .002 without endangering personnel of equipment.**

3. **Instructor will grade student's performance on setup and operating a surface grinder to a tolerance of .002 without endangering personnel of equipment.**

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

Name________________________________ Date__________________

CNC-F8
Operate Grinding/Abrasive Machines
Self-Assessment

Circle the letter preceding the correct answer.

1. The most widely used abrasive in manufacturing, the purer grades are almost white in color. Used mostly on hardened steels, this abrasive can work poorly on cast iron because, at the temperatures generated by grinding, it may be somewhat soluble in cast iron. Which abrasive is this?
   - A. Aluminum Oxide
   - B. Silicon Carbide
   - C. Cubic Boron Nitride
   - D. Diamond
   - E. None of the above answers is correct.

2. This abrasive is useful on cast iron, titanium alloys, copper alloys, and other non-ferrous alloys. While it works well on carbide cutting tools, it has largely been supplanted by another abrasive which abrades at lower temperatures. Which abrasive is this?
   - A. Aluminum Oxide
   - B. Silicon Carbide
   - C. Cubic Boron Nitride
   - D. Diamond
   - E. None of the above answers is correct.

3. General Electric Company introduced this abrasive commercially in 1969. It works very well on cobalt and nickel superalloys. While the cost of this abrasive is high, it results in faster cutting, less dressing, more consistent sizing, and less frequent wheel replacement. Which abrasive is this?
   - A. Aluminum Oxide
   - B. Silicon Carbide
   - C. Cubic Boron Nitride
   - D. Diamond
   - E. None of the above answers is correct.

4. **A common application of this superabrasive is the single-crystal nib used to true and dress grinding wheels. It is also used on tungsten alloys and ceramics, but its extreme cost limits its use to those applications in which it is virtually the only abrasive practical. This is the hardest material known. Which abrasive is this?**
   A. Aluminum Oxide
   B. Silicon Carbide
   C. Cubic Boron Nitride
   D. Diamond
   E. None of the above answers is correct.

5. Which of the following is ***not*** one of the five most common wheel shapes?
   A. Type 1—Straight wheel
   B. Type 4—Cylinder wheel
   C. Type 11—Flaring cup wheel with interior and exterior grinding faces
   D. All of the above are common shapes for grinding wheels.
   E. None of the above answers is correct.

All grinding wheels are marked with an alphanumeric code on the blotter. For Questions 6 through 10, refer to the following code:

B 36 — J12V

6. The first letter stands for the wheel's ___; the B stands for ___.
   A. Type of abrasive . . . silicon carbide
   B. Type of abrasive . . . cubic boron nitride
   C. Hardness . . . silicon carbide
   D. Hardness . . . cubic boron nitride
   E. None of the above answers is correct.

7. The first number stands for the ___, and can range from ___.
   A. Grit . . . 40 to 500
   B. Hardness . . . 40 to 500
   C. Grit . . . 4 to 500+
   D. Hardness . . . 4 to 500+
   E. None of the above answers is correct.

8. The second letter indicates the ___; the letters increase in hardness from ___.
   A. Strength of bond . . . F to Z
   B. Strength of bond . . . A to Z
   C. Hardness grade . . . R to Z
   D. Hardness grade . . . A to Z
   E. None of the above answers is correct.

9. The second number indicates the ___; the 12 means ___.
   - A. Grit . . . coarse grade
   - B. Grit . . . medium grade
   - C. Grain spacing . . . open structure
   - D. Grain spacing . . . dense structure
   - E. None of the above answers is correct.

10. The third letter and final symbol indicates the ___. The V is ___ in the machine shop.
   - A. Matrix . . . common
   - B. Matrix . . . rare
   - C. Bond . . . rare
   - D. Bond . . . common
   - E. None of the above answers is correct.

11. What is *swarf?*
   - A. The fine particles that come off the workpiece when it is ground.
   - B. The sparks given off by the workpiece as it is ground.
   - C. The retreat of waves from the beach, the complement of *surf.*
   - D. Both A & B.
   - E. None of the above answers is correct.

12. Which of the following is *not* a factor in wheel selection?
   - A. Composition of workpiece
   - B. Cutting fluids
   - C. Machine horsepower
   - D. All of the above are factors in wheel selection.
   - E. None of the above answers is correct.

13. What is meant by *trueing the wheel?*
   - A. Removing the dull grains from the wheel
   - B. Removing the embedded swarf from the wheel
   - C. Aligning the wheel with the center of its axis of rotation
   - D. Both A & B
   - E. None of the above answers is correct.

14. What is meant by *dressing the wheel?*
   - A. Removing the dull grains from the wheel
   - B. Removing the embedded swarf from the wheel
   - C. Aligning the wheel with the center of its axis of rotation
   - D. Both A & B
   - E. None of the above answers is correct.

15. Diamond wheels have machined bores so that:
  A. They will fit the spindle closely and truly.
  B. The grit and bond will not take up most of the wheel.
  C. They can be used on grinders of different manufacture.
  D. All of the above answers are correct.
  E. None of the above answers is correct.

16. The acceptable ratio of volume of abrasive loss to volume of workpiece removal (grinding ratio) for conventional abrasives is:
  A. 100:1.
  B. 80:1.
  C. 40:1.
  D. 20:1.
  E. None of the above answers is correct.

17. Which of the following is *not* a problem in grinding?
  A. Chatter
  B. Burning the workpiece
  C. Scratches on work
  D. All of the above are problems in grinding.
  E. None of the above answers is correct.

18. In cylindrical grinding, the workpiece is rotated ___ the rotation of the grinding wheel.
  A. By
  B. With
  C. Against
  D. The direction of relative rotation depends on the job at hand.
  E. None of the above answers is correct.

19. In general, a grinder can generate a temperature as high as ___ degrees Fahrenheit at the point of contact with the workpiece.
  A. 200
  B. 500
  C. 1000
  D. 2000
  E. None of the above answers is correct.

20. Match the following surface grinder types to their physical descriptions:
A. Horizontal spindle with reciprocating table
B. Vertical spindle with either reciprocating or rotary table
C. Horizontal spindle with rotary table

Type I ___

Type II ___

Type III ___

CNC-F8
Operate Grinding/Abrasive Machines
Self-Assessment Answer Key

1. A
2. B
3. C
4. D
5. B
6. B
7. C
8. A
9. C
10. D
11. D
12. D
13. C
14. D
15. A
16. C
17. D
18. C
19. D
20. Type I A

    Type II C

    Type III B

CNC MACHINIST .... programs, edits, sets up, and operates CNC lathes, mills and grinders to perform machining operations necessary to produce workpieces to referenced engineering standards.

	Duties	Tasks												
A	Practice Safety	A-1 Follow safety manuals and all safety regulations/ requirements	A-2 Use protective equipment	A-3 Follow safe operating procedures for hand and machine tools	A-4 Maintain a clean and safe work environment	A-5 MSDS/ control chemical hazards								
B	Apply Mathematical Concepts	B-1 Perform basic arithmetic functions	B-2 Convert fractions/ decimals	B-3 Convert Metric/ English measurements	B-4 Perform basic algebraic operations	B-5 Use practical geometry	B-6 Understand basic trigonometry	B-7 Calculate speeds and feeds for machining	B-8 Use coordinate systems					
C	Interpret Engineering Drawings and Control Documents	C-1 Identify basic layout of drawings	C-2 Identify basic types of drawings	C-3 Review blueprint notes and dimensions	C-4 List the purpose of each type of drawing	C-5 Verify drawing elements	C-6 Practice Geometric Dimensioning and Tolerancing (GD&T)	C-7 Analyze bill of materials (BOM)	C-8 Describe the relationship of engineering drawings to planning	C-9 Understand and use quality systems	C-10 Verify standard requirements			
D	Recognize Different Manufacturing Materials and Processes	D-1 Identify materials with desired properties	D-2 Identify materials and processes to produce a part	D-3 Describe the heat treating process	D-4 Test metal samples for hardness	D-5 Understand welding operations								
E	Measure/ Inspect	E-1 Understand metrology terms	E-2 Select measurement tools	E-3 Measure with hand held instruments	E-4 Eliminate measurement variables	E-5 Measure/ inspect using surface plate and accessories	E-6 Inspect using stationary equipment							
F	Perform Conventional Machining	F-1 Prepare and plan for machining operations	F-2 Use hand tools	F-3 Operate power saws	F-4 Operate drill presses	F-5 Operate vertical milling machines	F-6 Operate horizontal milling machines	F-7 Operate metal cutting lathes	F-8 Operate grinding/ abrasive machines					
G	Perform Advanced Machining	G-1 Understand CNC basics	G-2 Program CNC machines	G-3 Operate CNC machining centers (mills)	G-4 Operate CNC turning centers (lathes)									
H	Use Verification and Communication Systems	H-1 Use personal computer	H-2 Use various operating systems	H-3 Use computer communications systems	H-4 Use verification systems	H-5 Use the Internet								
I	Program Using CAM System	I-1 Understand CAD/ CAM programs	I-2 Manipulate CAD functions	I-3 Process simple tool-path data	I-4 Create advanced surface models	I-5 Process complex tool-path functions								

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DutyG

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-G1

Subject: **Advanced CNC and CAM** **Time: 15 Hrs.**

Duty: **Perform Advanced Machining**
Task: Understand CNC Basics

Objectives:

Upon completion of this module the student will be able to:
a. Identify and describe essentials and safety of CNC systems;
b. Identify and describe types of CNC hardware and software;
c. Identify and describe machine axes and coordinate systems; and,
d. Identify and describe coordinate systems.

Instructional Materials:

MASTER Handout (CNC-G1-HO)
MASTER Self-Assessment

References:

Computer Numerical Control, From Programming to Networking, S.C. Jonathan Lin, Delmar Publishers Inc., Latest Edition

Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-A1 through CNC-A5	"Practice Safety"
CNC-B1 through CNC-B8	"Apply Mathematical Concepts"
CNC-C1 through CNC-C10	"Interpret Engineering Drawings and Control Documents"
CNC-D1 through CNC-D5	"Recognize Different Manufacturing Materials and Processes"
CNC-E1 through CNC-E6	"Measure/Inspect"
CNC-F1 through CNC-F8	"Perform Conventional Machining"

Introduction:

In the modern world of machining more and more companies are relying heavily on CNC machinery. This is a trend that is expected to continue into the future of machine technology. Many students are highly motivated to learn how to program and operate this type of equipment. It is wise to have a basic understanding of how the equipment functions so we can have a better understanding of how to program the machine tool operations. Many of the procedures can be compared directly to their conventional machine counterparts. Most people will progress further along if they establish a solid foundation in the basic principles.

Presentation Outline:

I. Identify and Describe Essentials and Safety of CNC Systems
  A. Identify and explain essentials
    1. Define numerical control
    2. Explain history and future of CNC technology
    3. Identify basic elements of CNC system
    4. Define Computer Numerical Control (CNC)
    5. Explain advantages and limitations of CNC
    6. Identify applications of CNC technology
  B. Compare types of CNC systems
    1. Identify and describe modes on numerical control systems
    2. Explain difference between the following:
      a. Point-to-point
      b. Axial path
      c. 45° line type
      d. Linear path
      e. Continuous path
    3. Describe CNC interpolation
    4. Identify types of CNC interpolations
    5. Explain difference between open loop and closed loop systems
    6. List benefits and problems of open and closed loop systems
  C. Demonstrate safety practices related to CNC systems
    1. Demonstrate safety practices, including:
      a. Safety guard/door interlocks
      b. Power box interlocks
      c. Tool loading and unloading
      d. Loading and unloading work holding devices
      e. Machine coolant disposal
    2. Describe/identify personal safety equipment

II. Identify and Describe Types of CNC Hardware and Software
  A. Identify and describe CNC hardware
    1. Compare NC and CNC systems
    2. Identify components of CNC machine control unit (MCU)
    3. Define applications of operator control panel
    4. Explain functions of operator control panel
    5. Define utilities found on typical control panel

    - 6. Select appropriate CNC controls
  - B. Describe CNC software
    - 1. Describe software related to machine tool
    - 2. Describe applications of operation, interface and application software
    - 3. Describe interface of software and hardware
  - C. Explain feed back drive system
    - 1. Describe feed drive system
    - 2. Explain feed back mechanisms
    - 3. Compare direct and indirect measurement systems
- III. Identify and Describe Machine Axes and Coordinate Systems
  - A. Identify and describe machine axes
    - 1. Define and identify machine axes X, Y and Z
    - 2. Identify and describe linear axes using right hand rule
    - 3. Identify and define primary rotary axes A, B and C
  - B. Describe coordinate systems
    - 1. Describe Cartesian coordinate system as used in NC program
    - 2. Define relationship of Cartesian coordinate system with machine axes
  - C. Define characteristics of positioning systems
    - 1. Define application of absolute positioning systems
    - 2. Define application of incremental positioning systems .
  - D. Define reference systems
    - 1. Describe characteristics of:
      - a. Machine reference coordinates
      - b. Work reference coordinates
      - c. Program reference coordinates
      - d. Fixtures offset coordinates
- IV. Describe and Interpret CNC Coding Systems
  - A. Interpret number bases
    - 1. Interpret decimal and binary bases
    - 2. Interpret octal and hexadecimal bases
  - B. Describe NC program storage media
    - 1. Describe the media
    - 2. Describe advantages and disadvantages of each media
  - C. Describe EIA and ASCII formatted tapes
    - 1. Describe EIA format on tapes
    - 2. Describe ASCII format on tapes
    - 3. Describe differences in EIA and ASCII formats

Practical Application:

Evaluation and/or Verification:

Successful completion of this Technical Module will be based on the student's successful completion of the written evaluation.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-G2) dealing with programming CNC machines.

CNC-G1-HO
Understand CNC Basics
Attachment 1: **MASTER** Handout

Objectives:

Upon completion of this module the student will be able to:

a. Identify and describe essentials and safety of CNC systems;
b. Identify and describe types of CNC hardware and software;
c. Identify and describe machine axes and coordinate systems; and,
d. Identify and describe coordinate systems.

Module Outline:

I. Identify and Describe Essentials and Safety of CNC Systems
  A. Identify and explain essentials
    1. Define numerical control
    2. Explain history and future of CNC technology
    3. Identify basic elements of CNC system
    4. Define Computer Numerical Control (CNC)
    5. Explain advantages and limitations of CNC
    6. Identify applications of CNC technology
  B. Compare types of CNC systems
    1. Identify and describe modes on numerical control systems
    2. Explain difference between the following:
      a. Point-to-point
      b. Axial path
      c. 45° line type
      d. Linear path
      e. Continuous path
    3. Describe CNC interpolation
    4. Identify types of CNC interpolations
    5. Explain difference between open loop and closed loop systems
    6. List benefits and problems of open and closed loop systems
  C. Demonstrate safety practices related to CNC systems
    1. Demonstrate safety practices, including:
      a. Safety guard/door interlocks
      b. Power box interlocks
      c. Tool loading and unloading
      d. Loading and unloading work holding devices
      e. Machine coolant disposal
    2. Describe/identify personal safety equipment
II. Identify and Describe Types of CNC Hardware and Software
  A. Identify and describe CNC hardware

1. Compare NC and CNC systems
2. Identify components of CNC machine control unit (MCU)
3. Define applications of operator control panel
4. Explain functions of operator control panel
5. Define utilities found on typical control panel
6. Select appropriate CNC controls

B. Describe CNC software
   1. Describe software related to machine tool
   2. Describe applications of operation, interface and application software
   3. Describe interface of software and hardware

C. Explain feed back drive system
   1. Describe feed drive system
   2. Explain feed back mechanisms
   3. Compare direct and indirect measurement systems

III. Identify and Describe Machine Axes and Coordinate Systems

A. Identify and describe machine axes
   1. Define and identify machine axes X, Y and Z
   2. Identify and describe linear axes using right hand rule
   3. Identify and define primary rotary axes A, B and C

B. Describe coordinate systems
   1. Describe Cartesian coordinate system as used in NC program
   2. Define relationship of Cartesian coordinate system with machine axes

C. Define characteristics of positioning systems
   1. Define application of absolute positioning systems
   2. Define application of incremental positioning systems

D. Define reference systems
   1. Describe characteristics of:
      a. Machine reference coordinates
      b. Work reference coordinates
      c. Program reference coordinates
      d. Fixtures offset coordinates

IV. Describe and Interpret CNC Coding Systems

A. Interpret number bases
   1. Interpret decimal and binary bases
   2. Interpret octal and hexadecimal bases

B. Describe NC program storage media
   1. Describe the media
   2. Describe advantages and disadvantages of each media

C. Describe EIA and ASCII formatted tapes
   1. Describe EIA format on tapes
   2. Describe ASCII format on tapes
   3. Describe differences in EIA and ASCII formats

Name____________________________ Date:_____________________

CNC-G1
Understand CNC Basics
Self-Assessment

Circle the letter preceding the correct answer.

1. The definition "a system in which actions are controlled by the insertion of numerical data at some point" refers to?
    - A. Direct Numerical Control
    - B. Distributive Numerical Control
    - C. Numerical Control
    - D. Computerized Numerical Control

2. Which company is given credit for creating the first numerical control milling machine?
    - A. Rohr Industries
    - B. Massachusetts Institute of Technology
    - C. Parsons Corporations
    - D. General Electric

3. The term CNC stands for?
    - A. Continuous Numerical Control
    - B. Centerline Numerical Control
    - C. Computerized Numerical Control
    - D. Computerized Numerical Counter

4. The term DNC has multiple definitions one is:
    - A. Distinct numerical control
    - B. Desired numerical control
    - C. Direct numerical control
    - D. Destination numerical control

5. The term DNC has multiple definitions another one is:
    - A. District numerical control
    - B. Distributive numerical control
    - C. Distinctive numerical control
    - D. Desired numerical control

6. Examples of basic elements of a CNC system would include:
    - A. Center drill
    - B. Milling cutters
    - C. Mouse
    - D. Part program

7. Examples of basic elements of a CNC system would include:
   - A. Anilam
   - B. Program input device
   - C. Pocket calculator
   - D. Coolant

8. Examples of basic elements of a CNC system would include:
   - A. Machine control unit
   - B. Outside micrometer
   - C. Pencil and paper
   - D. Basic understanding of mathematics

9. Examples of basic elements of a CNC system would include:
   - A. Barcoding system
   - B. Inside micrometer
   - C. Drive systems
   - D. Basic understanding of engineering drawings

10. Examples of basic elements of a CNC system would include:
    - A. Machine tool
    - B. Basic theory of metal removal
    - C. Dial calipers
    - D. Windows operating system

11. Examples of basic elements of a CNC system would include:
    - A. Clamping devices
    - B. Depth micrometers
    - C. Feedback systems
    - D. Fine surface finishes

12. NC systems are often referred to as:
    - A. Primary memory
    - B. Softwired
    - C. Hardwired
    - D. Secondary memory

13. CNC systems are often referred to as:
    - A. Primary memory
    - B. Softwired
    - C. Hardwired
    - D. Secondary memory

14. Examples of advantages of CNC would include:
    A. High cost of cutting tools
    B. Increased productivity
    C. Highly attractive machines
    D. More interesting for maintenance workers

15. Examples of advantages of CNC would include:
    A. Lower number of pallets needed
    B. Increased electronics
    C. Inch and metric calibrations
    D. High accuracy and repeatability

16. Examples of advantages of CNC would include:
    A. Reduced production costs
    B. Systems require less attention
    C. Cost effective for small production runs
    D. Lower maintenance requirements

17. Examples of advantages of CNC would include:
    A. Reduced initial investment
    B. Reduced indirect operating costs
    C. Cost effective for small production runs
    D. Lower maintenance requirements

18. CNC operators have to have a higher skill level then a precision tool maker
    A. True
    B. False

19. Examples of disadvantages (limitations) of CNC would include:
    A. High cost of cutting tools
    B. Higher productivity
    C. High initial investment
    D. High probability of human error

20. Examples of disadvantages (limitations) of CNC would include:
    A. Higher scrap rates
    B. Higher Maintenance requirements
    C. Higher machine utilization
    D. High probability of human error

21. Examples of disadvantages (limitations) of CNC would include:
    A. Not cost effective for precision parts
    B. Not cost effective for alloys
    C. Not cost effective for low production levels
    D. Not cost effective for non ferrous metals

22. CNC can only be applied to applications of chip removal.
    A. True
    B. False

23. The addition of CNC machines guarantees increased productivity.
    A. True
    B. False

24. CNC programming has been dramatically changed by the advent of:
    A. Fiber optics
    B. CAD/CAM
    C. Space age coolants
    D. Special applications

25. The Point to Point control system is most often used in __________ operations.
    A. Rough machining
    B. Pocket machining
    C. Drilling
    D. Contouring

26. The Continuous-Path control system is often called _________________ system.
    A. Rough machining
    B. Pocket machining
    C. Drilling
    D. Contouring

27. The Continuous-Path control system is limited since it can only move one axis at a time.
    A. True
    B. False

28. An example of a function of the CNC interpolator would include:
    A. Generates spindle speed calculations for efficient material removal
    B. Generates intermediate coordinate positions along the program path
    C. Generates the proper feed rate in program
    D. Generates a complete list of "G" codes as needed by the machine

29. An example of a function of the CNC interpolator would include:
    A. Computes coolant selections for machine tool as needed
    B. Computes separate tool changes as needed
    C. Computes individual axis velocities as needed
    D. Computes material finish requirements as needed

30. One example of a common interpolation would be:
   A. Metabolic
   B. Bicubic approximation
   C. Linear
   D. Helical cubic NURB

31. One example of a common interpolation would be:
   A. Eliptoidinal
   B. Bi nurdic eliptoidinal
   C. Radius
   D. Circular

32. One significant feature of the _______________ control system is that there is no feedback signal for checking whether the programmed position has been reached.
   A. Closed loop
   B. Open loop
   C. NC
   D. CNC

33. One significant feature of the _______________ control system is that there are feedback signals that check whether the programmed position has been reached.
   A. Closed loop
   B. Open loop
   C. NC
   D. CNC

34. The _________________ control system is usually used with the Point to Point systems.
   A. Closed loop
   B. Open loop
   C. NC
   D. CNC

35. The _________________ control system is usually used with Continuous Path systems.
   A. Closed loop
   B. Open loop
   C. NC
   D. CNC

36. The acronym MCU stands for:
   - A. Machine Companies Unification
   - B. Machine control unit
   - C. Machine control university
   - D. Machine control union

37. Examples of primary memory would include:
   - A. Floppy disks
   - B. Hard drives
   - C. RAM
   - D. Paper tape

38. Examples of primary memory would include:
   - A. Greco system
   - B. DNC
   - C. ROM
   - D. Punch cards

39. Examples of secondary memory would include:
   - A. Greco system
   - B. DNC
   - C. ROM
   - D. Hard drives

40. Examples of secondary memory would include:
   - A. Floppy disks
   - B. Greco system
   - C. RAM
   - D. Paper tape

41. Machine ______________ is what allows us to reach a exact desired point coordinate.
   - A. Controller
   - B. Repeatability
   - C. Accuracy
   - D. Programming

42. Machine ______________ is what allows us to come back to an exact point coordinate time after time.
   - A. Controller
   - B. Repeatability
   - C. Accuracy
   - D. Programming

43. The ______________ measurement feedback system is free from the effects of machine backlash.
A. Indirect
B. Direct
C. Closed loop
D. Open loop

44. The ______________ measurement feedback system is effected by machine backlash.
A. Indirect
B. Direct
C. Closed loop
D. Open loop

45. The ______________ measurement feedback system is more accurate.
A. Indirect
B. Direct
C. Closed loop
D. Open loop

46. The machine axis designation by X,Y, and Z are the ___________ machine axis.
A. Tertiary linear
B. Primary linear
C. Secondary linear
D. Primary rotary

47. The machine axis designation by A,B and C are the ____________ machine axis.
A. Tertiary rotary
B. Primary rotary
C. Secondary rotary
D. Primary linear

48. The Cartesian coordinate system is often referred to as the ______________ coordinate system.
A. Polar
B. Secondary
C. Rectangular
D. Primary

49. The data point X-1.0 Y-2.0 is located in the number ______________ quadrant.
A. 1
B. 2
C. 3
D. 4

50. The data point X 1.0 Y 2.0 is located in the number ______________ quadrant.
A. 1
B. 2
C. 3
D. 4

51. The data point X 1.0 Y- 2.0 is located in the number ___________ quadrant.
A. 1
B. 2
C. 3
D. 4

52. The data point X- 1.0 Y 2.0 is located in the number ___________ quadrant.
A. 1
B. 2
C. 3
D. 4

53. The ___________ coordinate system defines the position of a point by its radius and an angle of rotation.
A. Polar
B. Secondary
C. Rectangular
D. Primary

54. If a data point was rotated 100 degrees from 0 it would be in the number ___________ quadrant.
A. 1
B. 2
C. 3
D. 4

55. If a data point was rotated 295 degrees from 0 it would be in the number ___________ quadrant.
A. 1
B. 2
C. 3
D. 4

56. If a data point was rotated 40 degrees from 0 it would be in the number __________ quadrant.
A. 1
B. 2
C. 3
D. 4

57. If a data point was rotated 195 degrees from 0 it would be in the number __________ quadrant.
A. 1
B. 2
C. 3
D. 4

58. In the __________ positioning system all positions are measured from a single fixed point.
A. Incremental
B. Polar
C. Rectangular
D. Absolute

59. In the __________ positioning system, the reference point is not fixed and moves from data point to data point .
A. Incremental
B. Polar
C. Rectangular
D. Absolute

CNC-G1
Understand CNC Basics
Self-Assessment Answer Key

1.	D
2.	C
3.	C
4.	C
5.	B
6.	D
7.	B
8.	A
9.	C
10.	A
11.	C
12.	C
13.	B
14.	B
15.	D
16.	A
17.	B
18.	B
19.	C
20.	B
21.	C
22.	B
23.	B
24.	B
25.	C
26.	D
27.	B
28.	B
29.	C
30.	C
31.	D
32.	B
33.	A
34.	B
35.	A
36.	B
37.	C
38.	C
39.	D
40.	A
41.	C
42.	B
43.	B
44.	A
45.	B
46.	B
47.	B
48.	C
49.	C
50.	A
51.	D
52.	B
53.	A
54.	B
55.	B
56.	A
57.	C
58.	D
59.	A

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-G2

Subject: Advanced CNC and CAM **Time:** 48 Hrs.

Duty: **Perform Advanced Machining**
Task: Program CNC Machines

Objective(s):

Upon completion of this module the student will be able to:

a. Identify and describe the effects of material preparation to production;
b. Identify and describe the use of machine tool fixtures;
c. Identify and describe clamping principles and cautions;
d. Identify and describe the process of selecting proper cutting tools;
e. Identify and describe commonly used "G"codes;
f. Identify and describe commonly used "M"codes;
g. Calculate and program cutter speed and feeds, and depth of cut;
h. Describe and apply cutter compensation;
i. Identify and describe fixed cycles; and,
j. Trouble shoot common programming problems.

Instructional Materials:

MASTER Handout (CNC-G2-HO)
MASTER Laboratory Exercise (CNC-G2-LE)

References:

Computer Numerical Control, From Programming to Networking, S.C. Jonathan Lin, Delmar Publishers, Inc., Latest Edition
Tooling/Fixture catalog
Specific Programming Manual for CNC Machine

Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-A1 through CNC-A5	"Practice Safety"
CNC-B1 through CNC-B8	"Apply Mathematical Concepts"
CNC-C1 through CNC-C10	"Interpret Engineering Drawings and Control Documents"
CNC-D1 through CNC-D5	"Recognize Different Manufacturing Materials and Processes"

CNC-E1 through CNC-E6 "Measure/Inspect"
CNC-F1 through CNC-F8 "Perform Conventional Machining"
CNC-G1 "Understand CNC Basics"

Introduction:

Although CNC machines are capable of increasing productivity at any given company, the machines themselves are only part of the overall process. Due to the exceptional amount of control a CNC machine has, the machinist can attain much more productivity.

The planning process, from the selection of material preparation, to fixtures and cutting tool selection, can make the difference in whether a company will make or lose money on any given contract. Process planning has to be considered every time we contemplate creating a part.

This module is meant as an introduction to, or overview of, CNC programming. Many people feel that it is no longer important to be able to hand code a program due to the advent of CAD/CAM software. It is this author's opinion that nothing could be further from the truth. A good working knowledge of the programming language will allow the user to properly edit existing programs if needed, as well as write programs by hand.

Modern CAD/CAM software programs are not always the most efficient ends to all part programs, and not all companies have the resources to employ their use for every task.

It is important to understand from the previous modules that CNC machines are capable of a tremendous amount of productivity. The machines are incapable of thinking; they can only execute commands that are input to them in a proper and logical fashion. It is important to note that while many CNC machines share common NC codes, they may also differ slightly. This variance is especially notable in the fixed cycle commands, (G81-G89). It also should be pointed out that the programming of arc moves (G2 and G3) may require different methods of denoting their arc centers. *It is always advisable to review the programming manual for each specific machine.*

As with all things, communication is very important; in the case of CNC, we must be able to communicate with the machine in its language. The language of CNC is very simple, and, because it is very limited, it must be used exactly as called for by the manufacture who made the equipment.

Presentation Outline:

I. Plan Process for NC Operations
    A. Plan for raw material preparation
        1. Describe effect of material preparation on production

    2. Describe typical shapes of raw materials
    3. Describe effects of proper material preparation
    4. Describe ways to minimize wasted time and material
    5. Describe pre-machining of materials to avoid excessive CNC machine time
    6. Create material preparation plan for NC machining
  B. Plan use of machining fixtures
    1. Describe and identify various work holding devices
    2. Describe clamping principles and cautions
    3. Describe work piece locating principles
    4. Create plan for work holding devices and tooling selection on program planning sheet
  C. Select proper cutting tools
    1. List common types of tool alloys used for cutting tools
    2. Identify advantages and disadvantages of different alloys
    3. Evaluate prices for various alloys compared to productivity changes
    4. Compare various tool geometries and their effects on machining
    5. Select tooling based on various budget models
    6. Create tool planning list showing various models

II. Write NC Programs
  A. Create NC words
    1. Define NC characters, blocks and words
    2. Identify and describe commonly used NC codes
    3. Describe and create safe start blocks
    4. Combine NC codes to create part program
  B. Create NC programs
    1. Use absolute (G90) and incremental (G91) positioning
    2. Use rapid positioning (G00) and linear interpolation (G01)
    3. Use circular interpolation (G02) and (G03)
    4. Identify plane selections (G17, G18, G19)
  C. Apply proper plane selection to circular interpolation
    1. Define and describe axis modifiers (I, J, K)
    2. Apply to circular interpolation (absolute and incremental type)
  D. Calculate and program cutter speed and cutter compensation
    1. Describe cutter compensation commands (G40, G41, G42)
    2. Describe relationships associated with G41 and climb milling
    3. Describe relationship associated with G42 and conventional milling
  E. Evaluate reference documentation to establish machinability factors for RPM equation
    1. Apply RPM calculations to identify proper spindle speed "S" word
    2. Calculate and program cutter feed and depth of cut
    3. Evaluate reference documentation to establish feed rate factors

    4. Apply depth of cut calculations for programming efficiency
    5. Apply feed equation to establish correct feed "F" word
F. Program tool selection and unit input systems
    1. Describe and apply unit input code (G70 and G71) correctly
    2. Describe tool function "T" word and its use
    3. Describe retract quill to Z machine home "M6"
    5. Describe and apply "T" word with "M6" to create tool change
G. Apply "M" codes to program
    1. Describe and list common "M" words and their applications
    2. Describe "M00" program stop and "M01" optional stop applications
    3. Describe "M02" end of program and "M30" end of tape
H. Program spindle operation
    1. Identify spindle commands
    2. Describe "M03" spindle on clockwise and "M04" spindle on counterclockwise
    3. Describe "M05" stop spindle
    4. Identify and describe coolant commands "M07", "M08" and "M09"
    5. Apply "M" codes to program
I. Program fixed cycles
    1. Identify and describe fixed cycles "G81 - G89"
    2. Describe benefits and time saving by using fixed cycles in programming
    3. Explain different fixed cycle formats for different controllers
    4. Apply fixed cycles to programs
J. Program operator messages
    1. Identify and describe non-machine code "operator messages"
    2. Describe symbols to isolate operator messages from program
        a. "*"
        b. "( )"
K. Apply operator messages to NC part program as needed

Practical Application:

1. Create a basic tooling list and have the students (in teams) cost out and justify the tooling for the list. As you are doing this, have them debate the use of tooling fixtures from the perspective of cost and the effect on production. Have them cost out a simple tooling fixture and decide at what level of production it is cost effective.
2. Create a drawing that incorporates the most common moves that your equipment has available and also what is common in your area, this will give the students a basic program to write and see what it actually does. I have my students calculate the cutter compensation for their first program instead of

using G41/G42; this reinforces their math skills. I also don't allow them to use the "Fixed" cycles in their first program. This helps them reinforce their basic programming codes.

3. Have the students present their programs to the class at various stages of completion; as a group they can troubleshoot possible problems.

Evaluation and/or Verification:

The student exercise listed in the Practical Application section will verify that the students understand the information. The instructor may also want to make out a list of various types of tooling and have the students as individuals develop cost sheets and justifications for their selections based on possible productivity increases.

Summary:

Review the main lesson points and answer students questions

Next Lesson Assignment:

MASTER Technical Module (CNC-G3) dealing with operating CNC machining centers (mills).

CNC-G2-HO
Program CNC Machines
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this module the student will be able to:
- a. Identify and describe the effects of material preparation to production;
- b. Identify and describe the use of machine tool fixtures;
- c. Identify and describe clamping principles and cautions;
- d. Identify and describe the process of selecting proper cutting tools;
- e. Identify and describe commonly used "G"codes;
- f. Identify and describe commonly used "M"codes;
- g. Calculate and program cutter speed and feeds, and depth of cut;
- h. Describe and apply cutter compensation;
- i. Identify and describe fixed cycles; and,
- j. Trouble shoot common programming problems.

Module Outline:

- I. Plan Process for NC Operations
  - A. Plan for raw material preparation
    - 1. Describe effect of material preparation on production
    - 2. Describe typical shapes of raw materials
    - 3. Describe effects of proper material preparation
    - 4. Describe ways to minimize wasted time and material
    - 5. Describe pre-machining of materials to avoid excessive CNC machine time
    - 6. Create material preparation plan for NC machining
  - B. Plan use of machining fixtures
    - 1. Describe and identify various work holding devices
    - 2. Describe clamping principles and cautions
    - 3. Describe work piece locating principles
    - 4. Create plan for work holding devices and tooling selection on program planning sheet
  - C. Select proper cutting tools
    - 1. List common types of tool alloys used for cutting tools
    - 2. Identify advantages and disadvantages of different alloys
    - 3. Evaluate prices for various alloys compared to productivity changes
    - 4. Compare various tool geometries and their effects on machining
    - 5. Select tooling based on various budget models
    - 6. Create tool planning list showing various models
- II. Write NC Programs

A. Create NC words
   1. Define NC characters, blocks and words
   2. Identify and describe commonly used NC codes
   3. Describe and create safe start blocks
   4. Combine NC codes to create part program

B. Create NC programs
   1. Use absolute (G90) and incremental (G91) positioning
   2. Use rapid positioning (G00) and linear interpolation (G01)
   3. Use circular interpolation (G02) and (G03)
   4. Identify plane selections (G17, G18, G19)

C. Apply proper plane selection to circular interpolation
   1. Define and describe axis modifiers (I, J, K)
   2. Apply to circular interpolation (absolute and incremental type)

D. Calculate and program cutter speed and cutter compensation
   1. Describe cutter compensation commands (G40, G41, G42)
   2. Describe relationships associated with G41 and climb milling
   3. Describe relationship associated with G42 and conventional milling

E. Evaluate reference documentation to establish machinability factors for RPM equation
   1. Apply RPM calculations to identify proper spindle speed "S" word
   2. Calculate and program cutter feed and depth of cut
   3. Evaluate reference documentation to establish feed rate factors
   4. Apply depth of cut calculations for programming efficiency
   5. Apply feed equation to establish correct feed "F" word

F. Program tool selection and unit input systems
   1. Describe and apply unit input code (G70 and G71) correctly
   2. Describe tool function "T" word and its use
   3. Describe retract quill to Z machine home "M6"
   5. Describe and apply "T" word with "M6" to create tool change

G. Apply "M" codes to program
   1. Describe and list common "M" words and their applications
   2. Describe "M00" program stop and "M01" optional stop applications
   3. Describe "M02" end of program and "M30" end of tape

H. Program spindle operation
   1. Identify spindle commands
   2. Describe "M03" spindle on clockwise and "M04" spindle on counterclockwise
   3. Describe "M05" stop spindle
   4. Identify and describe coolant commands "M07", "M08" and "M09"
   5. Apply "M" codes to program

I. Program fixed cycles

    1. Identify and describe fixed cycles “G81 - G89”
    2. Describe benefits and time saving by using fixed cycles in programming
    3. Explain different fixed cycle formats for different controllers
    4. Apply fixed cycles to programs

J. Program operator messages
    1. Identify and describe non-machine code “operator messages”
    2. Describe symbols to isolate operator messages from program
        a. “*”
        b. “()”

K. Apply operator messages to NC part program as needed

CNC-G2-LE
Program CNC Machines
Attachment 2: MASTER Laboratory Exercise

The student will:

1. Create a basic tooling list and have the students (in teams) cost out and justify the tooling for the list. As you are doing this, have them debate the use of tooling fixtures from the perspective of cost and the effect on production. Have them cost out a simple tooling fixture and decide at what level of production it is cost effective.

2. Create a drawing that incorporates the most common moves that your equipment has available and also what is common in your area, this will give the students a basic program to write and see what it actually does. I have my students calculate the cutter compensation for their first program instead of using G41/G42; this reinforces their math skills. I also don't allow them to use the "Fixed" cycles in their first program. This helps them reinforce their basic programming codes.

3. Have the students present their programs to the class at various stages of completion; as a group they can troubleshoot possible problems.

CNC-G3

ADVANCED CNC and CAM SERIES
MASTER Technical Module No. CNC-G3

Subject: **Advanced CNC and CAM** **Time: 50 Hrs.**

Duty: **Perform Advanced Machining**
Task: Operate CNC Machining Centers (Mills)

Objectives:

Upon completion of this module the student will be able to:

a. Describe history of vertical machining;
b. Describe theory of operation;
c. Describe nomenclature used in vertical machining;
d. Demonstrate safety practices related to vertical machining centers;
e. Set-up and program operation of vertical machine;
f. Demonstrate proper machining of objects;
g. Create program using machine controllers software, and cycles;
h. Set-up and utilize three dimensional digitizer; and,
i. Maintain vertical machine.

Instructional Materials:

MASTER Handout (CNC-G3-HO)

References:

Computer Numerical Control, From Programming to Networking, S.C. Jonathan Lin, Delmar Publishers Inc., Latest Edition
Programming Manual for Your CNC Machine

Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-A1 through CNC-A5	"Practice Safety"
CNC-B1 through CNC-B8	"Apply Mathematical Concepts"
CNC-C1 through CNC-C10	"Interpret Engineering Drawings and Control Documents"
CNC-D1 through CNC-D5	"Recognize Different Manufacturing Materials and Processes"
CNC-E1 through CNC-E6	"Measure/Inspect"
CNC-F1 through CNC-F8	"Perform Conventional Machining"
CNC-G1	"Understand CNC Basics"

CNC-G2 "Program CNC Machines"

Introduction:

With the introduction of the first NC machines, machining was changed forever. In the beginning, ownership of NC machines was limited to those companies that possessed great financial resources. The need for these machines, even if one had the capital, was limited to those companies that produced long production runs that required little (if any) design variation. These early machines were not user friendly nor were they quick to program, set up, or operate. The advent of modern computers along with major changes in associated electronics has changed this scenario forever. Today the vast majority of companies have at least one CNC machine if not many. Most of the new employment is offered in the use and programming of these machines. It is no longer an option as to whether a machinist wants to learn how to use a CNC machining center, but at what level of employment they expect to attain. The overall popularity of CNC machines is increasing dramatically and this trend demands that all machinists accept CNC as they have any other tool of their trade.

This module addresses the application of the CNC vertical machining center, which is really just a hybrid of the common milling machine, with the addition of many of its attachments.

This module can be used for individuals who will be using vertical machines at various levels from CNC operator to CNC machinists. The ability to complete these tasks both quickly and accurately in various settings will, in most cases, be one of the deciding factors of how long an individual will stay at the operator level or progress into the programming area.

It is important to note that not all individuals will acquire the ability to create programs either by choice or by some other limitation. Even with this limited scenario, there are opportunities in this field for competent operators who do not create the actual programs.

Presentation Outline:

I. Describe Vertical Machining Process and Safety
    A. Describe history of vertical machining
        1. Describe proper use of various machines
    B. Describe theory of operation
        1. Describe open and closed loop systems
        2. Describe various oil and air requirements
        3. Describe how vertical machines function
    C. Describe nomenclature used in vertical machining
        1. Describe common tools used to:

        - a. Mill
        - b. Single point thread
        - c. Drill
        - d. Single point bore
        - e. Tap
        - f. Reaming
      - 2. Describe solid and collet type tool holders
  - D. Demonstrate safety practices related to vertical machining centers
    - 1. Demonstrate operating safety practices, including:
      - a. Safety door interlocks
      - b. Machining vise loading and unloading
      - c. Power box interlocks
      - d. Machine coolant disposal
      - e. Tool loading and unloading
    - 2. Describe/identify personal safety equipment
- II. Describe Vertical Machining Functions
  - A. Describe controller functions, including:
    - 1. Power meter
    - 2. Automatic mode
    - 3. Key lock
    - 4. Emergency stop button
    - 5. Option switches
    - 6. Manual modes:
      - a. Command mode
      - b. MDI mode
    - 7. Rapid travel over ride
    - 8. Single step mode (block-To-block)
    - 9. Feed rate override
    - 10. Jog mode
    - 11. Spindle speed override
    - 12. Spindle on/off
    - 13. Axis selector
    - 14. Slide hold
    - 15. Increment of movement selector
    - 16. Coolant 1 and 2 on/off
    - 17. Tool in/out
    - 18. Start button
    - 19. Turret clockwise (CW) and turret counterclockwise (CCW)
    - 20. Start function
- III. Set-Up and Program Operation of Vertical Machine
  - A. Describe machine tool limitations, including:
    - 1. Number of possible tools
    - 2. Limits in X,Y and Z axes
    - 3. Maximum spindle speed and horsepower
    - 4. Memory size in controller

5. Fast feed rate
6. Oil and air requirements
7. Rapid positioning rate
8. Communication systems

B. Perform basic machine set-up
1. Check oil and air supply
2. Set tool changer numbers
3. Turn power on
4. Mount machine vise on machine table
5. Set machine home position
6. Indicate vise to within specified tolerances
7. Load tools into proper tool holders
8. Load part into vise
9. Load tools into tool carousel
a. Load tools using spindle
b. Load tools directly into carousel

C. Set part home
1. Set part home using edge finder
2. Set part home using test indicator and gauge block
3. Set part home from tooling ball using fixture offsets

D. Set tool length offsets
1. Set tool length offsets using work piece
2. Set tool length offsets using gauge block
3. Set tool length offsets using electronic probe
4. Set tool length offsets using keyboard commands
5. Modify length and diameter offsets using tool page editor.
6. Upload and download tool information to storage

E. Load program
1. Upload and download programs using RS-232 interface
2. Upload and download programs using local area network

F. Edit program for machine tool
1. Edit program at machine tool using editor in controller
2. Edit program using DOS and Windows editors

G. Create program without CAD/CAM for common machine operations using machine controllers software to include:
1. Proper use of cutter compensation
2. Fixed cycles
3. Fixed sub-routines
4. Sub-routines (loops)
5. Fixture offsets
6. Troubleshoot and repair problems in programs
7. Use machine verification options if available

IV. Demonstrate Machining of Objects on Vertical Machining Center

A. Machine objects, including:
1. Outside contours

    2. Pockets
    3. Drilled holes
    4. Drill and tapped holes
        a. Rigid tapping
        b. Compression tapping
    5. Single point boring
    6. Reaming
    7. Single point thread, internal and external

B. Set-up three dimensional digitizer and machine model
    1. Mount model on machine table
    2. Install 3-dimensional digitizing unit
    3. Establish communications with computer
    4. Define grid pattern and feed rate required for given tolerances
    5. Set part home
    6. Digitize model
    7. Process digital data for machining
    8. Machine new model with program created from digitizer

C. Create work piece using 4th- and 5th-axes
    1. Mount, connect and indicate 4th- and 5th-axes attachment
    2. Set-tooling
    3. Machine work piece
    4. Remove 4th- and 5th-axes attachment

D. Maintain vertical machine
    1. Mix coolant
    2. Determine need for coolant change
    3. Change coolant
    4. Clean coolant tank
    5. Clean machine
    6. Change oil filters
    7. Add lubricating fluid
    8. Add hydraulic fluid
    9. Dispose of coolant and oils per EPA regulations

Practical Application:

In our machine technology program we have found it very important to require the students to do all aspects of vertical machining. It should be obvious that if an individual cannot set up a machine, then he will be limited to just "pushing buttons."

We have created this module to be customized for not only a specific group of individuals, but also many different types of machines/controllers, as well as local manufacturer requirements.

Most of the areas of this module are generic to all vertical machines as well as most machine controllers. Please note that there can be a great variation from one machine type to another; this becomes very evident in many of the sections covered in this module.

It is very important that the instructor design projects that are progressive in the level of required sophistication, so that the students will be reinforced as to their ability to complete these requirements.

We have also discovered that it is helpful to have the students work in groups, as well as individually, on these projects. However, please point out to the students that team work is not always the way things are completed in industry, and individual subject mastery is critical to employment.

Evaluation and/or Verification:

As with the Practical Application section above it will be necessary for the instructor to design an evaluation instrument that best suits the environment in which the instructor is presenting this information.

It is important to remember that the subject mastery is represented in the ability to not only perform the application of the technology, but also the ability to explain the process in both oral and written format.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-G4) dealing with operating CNC turning centers (lathes).

CNC-G3-HO
Operate CNC Machining Centers (Mills)
Attachment 1: MASTER Handout

Objectives:

Upon completion of this module the student will be able to:

- a. Describe history of vertical machining;
- b. Describe theory of operation;
- c. Describe nomenclature used in vertical machining;
- d. Demonstrate safety practices related to vertical machining centers;
- e. Set-up and program operation of vertical machine;
- f. Demonstrate proper machining of objects;
- g. Create program using machine controllers software, and cycles;
- h. Set-up and utilize three dimensional digitizer; and,
- i. Maintain vertical machine.

Module Outline:

- I. Describe Vertical Machining Process and Safety
    - A. Describe history of vertical machining
        - 1. Describe proper use of various machines
    - B. Describe theory of operation
        - 1. Describe open and closed loop systems
        - 2. Describe various oil and air requirements
        - 3. Describe how vertical machines function
    - C. Describe nomenclature used in vertical machining
        - 1. Describe common tools used to:
            - a. Mill
            - b. Single point thread
            - c. Drill
            - d. Single point bore
            - e. Tap
            - f. Reaming
        - 2. Describe solid and collet type tool holders
    - D. Demonstrate safety practices related to vertical machining centers
        - 1. Demonstrate operating safety practices, including:
            - a. Safety door interlocks
            - b. Machining vise loading and unloading
            - c. Power box interlocks
            - d. Machine coolant disposal
            - e. Tool loading and unloading
        - 2. Describe/identify personal safety equipment
- II. Describe Vertical Machining Functions

- A. Describe controller functions, including:
  1. Power meter
  2. Automatic mode
  3. Key lock
  4. Emergency stop button
  5. Option switches
  6. Manual modes:
     - a. Command mode
     - b. MDI mode
  7. Rapid travel over ride
  8. Single step mode (block-To-block)
  9. Feed rate override
  10. Jog mode
  11. Spindle speed override
  12. Spindle on/off
  13. Axis selector
  14. Slide hold
  15. Increment of movement selector
  16. Coolant 1 and 2 on/off
  17. Tool in/out
  18. Start button
  19. Turret clockwise (CW) and turret counterclockwise (CCW)
  20. Start function

- III. Set-Up and Program Operation of Vertical Machine
  - A. Describe machine tool limitations, including:
    1. Number of possible tools
    2. Limits in X,Y and Z axes
    3. Maximum spindle speed and horsepower
    4. Memory size in controller
    5. Fast feed rate
    6. Oil and air requirements
    7. Rapid positioning rate
    8. Communication systems
  - B. Perform basic machine set-up
    1. Check oil and air supply
    2. Set tool changer numbers
    3. Turn power on
    4. Mount machine vise on machine table
    5. Set machine home position
    6. Indicate vise to within specified tolerances
    7. Load tools into proper tool holders
    8. Load part into vise
    9. Load tools into tool carousel
       - a. Load tools using spindle
       - b. Load tools directly into carousel

- C. Set part home
    - 1. Set part home using edge finder
    - 2. Set part home using test indicator and gauge block
    - 3. Set part home from tooling ball using fixture offsets
- D. Set tool length offsets
    - 1. Set tool length offsets using work piece
    - 2. Set tool length offsets using gauge block
    - 3. Set tool length offsets using electronic probe
    - 4. Set tool length offsets using keyboard commands
    - 5. Modify length and diameter offsets using tool page editor.
    - 6. Upload and download tool information to storage
- E. Load program
    - 1. Upload and download programs using RS-232 interface
    - 2. Upload and download programs using local area network
- F. Edit program for machine tool
    - 1. Edit program at machine tool using editor in controller
    - 2. Edit program using DOS and Windows editors
- G. Create program without CAD/CAM for common machine operations using machine controllers software to include:
    - 1. Proper use of cutter compensation
    - 2. Fixed cycles
    - 3. Fixed sub-routines
    - 4. Sub-routines (loops)
    - 5. Fixture offsets
    - 6. Troubleshoot and repair problems in programs
    - 7. Use machine verification options if available

IV. Demonstrate Machining of Objects on Vertical Machining Center

- A. Machine objects, including:
    - 1. Outside contours
    - 2. Pockets
    - 3. Drilled holes
    - 4. Drill and tapped holes
        - a. Rigid tapping
        - b. Compression tapping
    - 5. Single point boring
    - 6. Reaming
    - 7. Single point thread, internal and external
- B. Set-up three dimensional digitizer and machine model
    - 1. Mount model on machine table
    - 2. Install 3-dimensional digitizing unit
    - 3. Establish communications with computer
    - 4. Define grid pattern and feed rate required for given tolerances
    - 5. Set part home
    - 6. Digitize model
    - 7. Process digital data for machining

    8. Machine new model with program created from digitizer

C. Create work piece using 4th- and 5th-axes
    1. Mount, connect and indicate 4th- and 5th-axes attachment
    2. Set-tooling
    3. Machine work piece
    4. Remove 4th- and 5th-axes attachment

D. Maintain vertical machine
    1. Mix coolant
    2. Determine need for coolant change
    3. Change coolant
    4. Clean coolant tank
    5. Clean machine
    6. Change oil filters
    7. Add lubricating fluid
    8. Add hydraulic fluid
    9. Dispose of coolant and oils per EPA regulations

CNC-G4

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-G4

Subject: **Advanced CNC and CAM** **Time: 50 Hrs.**

Duty: **Perform Advanced Machining**
Task: Operate CNC Turning Centers (Lathes)

Objectives:

Upon completion of this module the student will be able to:
a. Describe history of horizontal turning centers;
b. Describe theory of operation;
c. Describe nomenclature used in horizontal turning centers;
d. Demonstrate safety practices related to horizontal turning centers;
e. Set-up and program operation of horizontal turning centers;
f. Demonstrate proper machining of objects;
g. Create program using machine controllers software; and,
h. Maintain horizontal turning centers.

Instructional Materials:

MASTER Handout (CNC-G4-HO)

References:

Computer Numerical Control, From Programming to Networking, S.C. Jonathan Lin, Delmar Publishers Inc., Latest Edition
Programming Manual for your CNC Machine

Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-A1 through CNC-A5	"Practice Safety"
CNC-B1 through CNC-B8	"Apply Mathematical Concepts"
CNC-C1 through CNC-C10	"Interpret Engineering Drawings and Control Documents"
CNC-D1 through CNC-D5	"Recognize Different Manufacturing Materials and Processes"
CNC-E1 through CNC-E6	"Measure/Inspect"
CNC-F1 through CNC-F8	"Perform Conventional Machining"
CNC-G1	"Understand CNC Basics"
CNC-G2	"Program CNC Machines"

CNC-G3 “Operate CNC Machining Centers (Mills)

Introduction:

With the introduction of the first NC machines, machining was changed forever. In the beginning, ownership of NC machines was limited to those companies that possessed great financial resources. The need for these machines, even if one had the capital, was limited to those companies that produced long production runs that required little (if any) design variation. These early machines were not user friendly nor were they quick to program, set up, or operate. The advent of modern computers, along with major changes in associated electronics, has changed this scenario forever. Today the vast majority of companies have at least one CNC machine if not many. Most of the new employment is offered in the use and programming of these machines. It is no longer an option as to whether a machinist wants to learn how to use a CNC machining center, but at what level of employment they expect to attain. The overall popularity of CNC machines is increasing dramatically and this trend demands that all machinists accept CNC as they have any other tool of their trade.

This module addresses the application of the CNC turning center, which is really just a hybrid of the common lathe, its conventional counterpart with the addition of many of its attachments.

This module can be used for individuals who will be using turning centers at various levels from CNC operator to CNC machinists. The ability to complete these tasks both quickly and accurately in various settings will, in most cases, be one of the deciding factors of how long an individual will stay at the operator level or progress into the programming area.

It is important to note that not all individuals will acquire the ability to create programs, either by choice or by some other limitation. Even with this limited scenario, there are opportunities in this field for competent operators who do not create the actual program.

Presentation Outline:

I. Explain CNC Turning Process, Equipment and Safety
    A. Describe CNC turning process
        1. Describe history of CNC turning
        2. Describe use of various turning machines
    B. Describe theory of operation
        1. Describe open and closed loop systems
        2. Describe various oil and air requirements
        3. Describe how turning centers function
    C. Describe nomenclature used in CNC turning

    1. Describe and identify common tools used to:
        a. Turn
        b. Drill
        c. Groove
        d. Face
        e. Bore
        f. Single point thread
        g. Tap
    2. Describe and identify work holding devices used in turning, including:
        a. 2-jaw chucks
        b. 3-jaw chuck
        c. 4-jaw chucks
        d. Soft jaw chucks
        e. Bar feed attachments
        f. Collets
        g. Centers
    3. Select proper cutting inserts relative to:
        a. Roughing
        b. Finishing
        c. Threading
        d. Different types of materials

D. Demonstrate safety practices related to CNC turning centers
    1. Demonstrate operating safety practices, including:
        a. Safety door interlocks
        b. Power box interlocks
        c. Tool loading and unloading
        d. Loading and unloading work holding devices
        e. Machine coolant disposal
    2. Describe/identify personal safety equipment

II. Describe CNC Turning Center

A. Describe controller functions, including:
    1. Power meter
    2. Option switches
    3. Key lock
    4. Emergency stop button
    5. Rapid travel override
    6. Feed rate override
    7. Spindle speed override
    8. Axis selector
    9. Increment of movement selector
    10. Slide hold
    11. Start function

B. Describe keyboard functions, including:
    1. Automatic mode

    - 2. Manual MDI mode
    - 3. Single step mode (block-to-block)
    - 4. Jog mode
    - 5. Spindle on/off
    - 6. Coolant on/off
    - 7. Tool turret clockwise (CW) and tool turret counterclockwise (CCW)

III. Set-Up and Program Operation of CNC Turning Center

- A. Describe machine tool limitations, including:
  - 1. Number of possible tools
  - 2. Maximum spindle speed and horsepower
  - 3. Fast feed rate
  - 4. Rapid positioning rate
  - 5. Limits in X and Z axes
  - 6. Memory size in controller
  - 7. Oil and air requirements
  - 8. Communication systems
- B. Perform basic machine set-up
  - 1. Check oil and air supply
  - 2. Turn power on
  - 3. Set machine home position
  - 4. Load tools into proper tool holders
  - 5. Load tools into tool carousel
  - 6. Set tool changer numbers
  - 7. Mount work piece into chuck
  - 8. Indicate work piece within specified tolerances
- C. Set tool length offsets
  - 1. Set tool length offsets using work piece
  - 2. Set tool length offsets using keyboard commands
  - 3. Modify length and diameter offsets using tool page editor
  - 4. Modify length and diameter offsets using keyboard
  - 5. Upload and download tool information to storage
- D. Load program
  - 1. Upload and download programs using RS-232 interface
  - 2. Upload and download programs using local area network
- E. Edit program for machine tool
  - 1. Edit program at machine tool using editor in controller
  - 2. Edit program using DOS and Windows editors

IV. Create Program Without CAD/CAM for Common Machine Operations Using Machine Controllers Software to include:

- A. Proper use of cutter compensation
- B. Fixed cycles
- C. Fixed sub-routines
- D. Sub-routines (loops)
- E. Fixture offsets

    F. Trouble shoot and repair problems in programs
    G. Use machine verification options if available
- V. Create Program for Common Machine Operations
    - A. Use machine controller editor
    - B. Use DOS editor
    - C. Use Windows editor
- VI. Demonstrate Machining of Objects on CNC Turning Center
    - A. Machine objects, including:
        1. External and internal contouring
        2. External and internal grooving
        3. Drill and tapped holes
        4. Single point boring
        5. Reaming
        6. Single point thread internal and external
        7. Facing operations
        8. Turning tapers
    - B. Maintain turning center
        1. Mix coolant
        2. Determine need for coolant change
        3. Change coolant
        4. Clean coolant tank
        5. Clean machine
        6. Change oil filters
        7. Add lubricating fluid
        8. Add hydraulic fluid
        9. Dispose of coolant and oils per EPA regulations

Practical Application:

In our machine technology program we have found it very important to require the students to do all aspects of CNC turning. It should be obvious that if an individual cannot set up a machine, then he will be limited to just "pushing buttons."

We have created this module to be customized for not only a specific group of individuals, but also many different types of machines/controllers, as well as local manufacturer requirements.

Most of the areas of this module are generic to all CNC turning centers as well as most machine controllers. Please note that there can be a great variation from one machine type to another; this becomes very evident in many of the sections covered in this module.

It is very important that the instructor design projects that are progressive in the level of required sophistication, so that the students will be reinforced as to their ability to complete these requirements.

We have also discovered that it is helpful to have the students work in groups, as well as individually, on these projects. However, please point out to the students that team work is not always the way things are completed in industry, and individual subject mastery is critical to employment.

Evaluation and/or Verification:

As with the Practical Application section above it will be necessary for you to design an evaluation instrument that best suits the environment in which you are presenting this information.

It is important to remember that the subject mastery is represented in the ability to not only perform the application of the technology, but also the ability to explain the process in both oral and written format.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-H1) dealing with using a personal computer.

CNC-G4-HO
Operate CNC Turning Centers (Lathes)
Attachment 1: MASTER Handout

Objectives:

Upon completion of this module the student will be able to:

a. Describe history of horizontal turning centers;
b. Describe theory of operation;
c. Describe nomenclature used in horizontal turning centers;
d. Demonstrate safety practices related to horizontal turning centers;
e. Set-up and program operation of horizontal turning centers;
f. Demonstrate proper machining of objects;
g. Create program using machine controllers software; and,
h. Maintain horizontal turning centers.

Module Outline:

I. Explain CNC Turning Process, Equipment and Safety
  A. Describe CNC turning process
    1. Describe history of CNC turning
    2. Describe use of various turning machines
  B. Describe theory of operation
    1. Describe open and closed loop systems
    2. Describe various oil and air requirements
    3. Describe how turning centers function
  C. Describe nomenclature used in CNC turning
    1. Describe and identify common tools used to:
      a. Turn
      b. Drill
      c. Groove
      d. Face
      e. Bore
      f. Single point thread
      g. Tap
    2. Describe and identify work holding devices used in turning, including:
      a. 2-jaw chucks
      b. 3-jaw chuck
      c. 4-jaw chucks
      d. Soft jaw chucks
      e. Bar feed attachments
      f. Collets
      g. Centers

    - 3. Select proper cutting inserts relative to:
      - a. Roughing
      - b. Finishing
      - c. Threading
      - d. Different types of materials
  - D. Demonstrate safety practices related to CNC turning centers
    - 1. Demonstrate operating safety practices, including:
      - a. Safety door interlocks
      - b. Power box interlocks
      - c. Tool loading and unloading
      - d. Loading and unloading work holding devices
      - e. Machine coolant disposal
    - 2. Describe/identify personal safety equipment
- II. Describe CNC Turning Center
  - A. Describe controller functions, including:
    - 1. Power meter
    - 2. Option switches
    - 3. Key lock
    - 4. Emergency stop button
    - 5. Rapid travel override
    - 6. Feed rate override
    - 7. Spindle speed override
    - 8. Axis selector
    - 9. Increment of movement selector
    - 10. Slide hold
    - 11. Start function
  - B. Describe keyboard functions, including:
    - 1. Automatic mode
    - 2. Manual MDI mode
    - 3. Single step mode (block-to-block)
    - 4. Jog mode
    - 5. Spindle on/off
    - 6. Coolant on/off
    - 7. Tool turret clockwise (CW) and tool turret counterclockwise (CCW)
- III. Set-Up and Program Operation of CNC Turning Center
  - A. Describe machine tool limitations, including:
    - 1. Number of possible tools
    - 2. Maximum spindle speed and horsepower
    - 3. Fast feed rate
    - 4. Rapid positioning rate
    - 5. Limits in X and Z axes
    - 6. Memory size in controller
    - 7. Oil and air requirements
    - 8. Communication systems

B. Perform basic machine set-up
   1. Check oil and air supply
   2. Turn power on
   3. Set machine home position
   4. Load tools into proper tool holders
   5. Load tools into tool carousel
   6. Set tool changer numbers
   7. Mount work piece into chuck
   8. Indicate work piece within specified tolerances

C. Set tool length offsets
   1. Set tool length offsets using work piece
   2. Set tool length offsets using keyboard commands
   3. Modify length and diameter offsets using tool page editor
   4. Modify length and diameter offsets using keyboard
   5. Upload and download tool information to storage

D. Load program
   1. Upload and download programs using RS-232 interface
   2. Upload and download programs using local area network

E. Edit program for machine tool
   1. Edit program at machine tool using editor in controller
   2. Edit program using DOS and Windows editors

IV. Create Program Without CAD/CAM for Common Machine Operations Using Machine Controllers Software to include:

   A. Proper use of cutter compensation
   B. Fixed cycles
   C. Fixed sub-routines
   D. Sub-routines (loops)
   E. Fixture offsets
   F. Trouble shoot and repair problems in programs
   G. Use machine verification options if available

V. Create Program for Common Machine Operations

   A. Use machine controller editor
   B. Use DOS editor
   C. Use Windows editor

VI. Demonstrate Machining of Objects on CNC Turning Center

   A. Machine objects, including:
      1. External and internal contouring
      2. External and internal grooving
      3. Drill and tapped holes
      4. Single point boring
      5. Reaming
      6. Single point thread internal and external
      7. Facing operations
      8. Turning tapers
   B. Maintain turning center

1. Mix coolant
2. Determine need for coolant change
3. Change coolant
4. Clean coolant tank
5. Clean machine
6. Change oil filters
7. Add lubricating fluid
8. Add hydraulic fluid
9. Dispose of coolant and oils per EPA regulations

CNC MACHINIST .... **programs, edits, sets up, and operates CNC lathes, mills and grinders to perform machining operations necessary to produce workpieces to referenced engineering standards.**

Duties		Tasks												
A	Practice Safety	A-1 Follow safety manuals and all safety regulations/ requirements	A-2 Use protective equipment	A-3 Follow safe operating procedures for hand and machine tools	A-4 Maintain a clean and safe work environment	A-5 MSDS/ control chemical hazards								
B	Apply Mathematical Concepts	B-1 Perform basic arithmetic functions	B-2 Convert fractions/ decimals	B-3 Convert Metric/ English measurements	B-4 Perform basic algebraic operations	B-5 Use practical geometry	B-6 Understand basic trigonometry	B-7 Calculate speeds and feeds for machining	B-8 Use coordinate systems					
C	Interpret Engineering Drawings and Control Documents	C-1 Identify basic layout of drawings	C-2 Identify basic types of drawings	C-3 Review blueprint notes and dimensions	C-4 List the purpose of each type of drawing	C-5 Verify drawing elements	C-6 Practice Geometric Dimensioning and Tolerancing (GD&T)	C-7 Analyze bill of materials (BOM)	C-8 Describe the relationship of engineering drawings to planning	C-9 Understand and use quality systems	C-10 Verify standard requirements			
D	Recognize Different Manufacturing Materials and Processes	D-1 Identify materials with desired properties	D-2 Identify materials and processes to produce a part	D-3 Describe the heat treating process	D-4 Test metal samples for hardness	D-5 Understand welding operations								
E	Measure/ Inspect	E-1 Understand metrology terms	E-2 Select measurement tools	E-3 Measure with hand held instruments	E-4 Eliminate measurement variables	E-5 Measure/ inspect using surface plate and accessories	E-6 Inspect using stationary equipment							
F	Perform Conventional Machining	F-1 Prepare and plan for machining operations	F-2 Use hand tools	F-3 Operate power saws	F-4 Operate drill presses	F-5 Operate vertical milling machines	F-6 Operate horizontal milling machines	F-7 Operate metal cutting lathes	F-8 Operate grinding/ abrasive machines					
G	Perform Advanced Machining	G-1 Understand CNC basics	G-2 Program CNC machines	G-3 Operate CNC machining centers (mills)	G-4 Operate CNC turning centers (lathes)									
H	Use Verification and Communication Systems	H-1 Use personal computer	H-2 Use various operating systems	H-3 Use computer communications systems	H-4 Use verification systems	H-5 Use the Internet								
I	Program Using CAM System	I-1 Understand CAD/ CAM programs	I-2 Manipulate CAD functions	I-3 Process simple tool-path data	I-4 Create advanced surface models	I-5 Process complex tool-path functions								

CNC P&M
[illegible]

Duty H

CNC-H1

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-H1

Subject: **Advanced CNC and CAM** **Time: 9 Hrs.**

Duty: **Use Verification and Communication Systems**
Task: Use Personal Computer

Objective(s):

Upon completion of this module the student will be able to:
a. Demonstrate proper use of personal computers;
b. Describe and identify various memory types and their functions;
c. Describe and identify main computer components and their applications; and,
d. Demonstrate ability to connect basic computer components.

Instructional Materials:

MASTER Handout (CNC-H1-HO)
MASTER Self-Assessment

References:

Computer Reference Manual that has come with your system; and,
Basic computer books you may already have, or that are easily available in your area.

Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-A1 through CNC-A5	"Practice Safety"
CNC-B1 through CNC-B8	"Apply Mathematical Concepts"
CNC-C1 through CNC-C10	"Interpret Engineering Drawings and Control Documents"
CNC-D1 through CNC-D5	"Recognize Different Manufacturing Materials and Processes"
CNC-E1 through CNC-E6	"Measure/Inspect"
CNC-F1 through CNC-F8	"Perform Conventional Machining"
CNC-G1 through CNC-G4	"Perform Advanced Machining"

Introduction:

The time has long since past that people use typewriters, adding machines, or flex writers. The computer has become a replacement tool to many of us no matter what our occupational field. The Machinist occupation is no exception. From the beginning of our trade, we have been involved in one of the most dynamic and technical fields that has ever existed; this field is ever changing. In the not too distant past it would have been unheard of for a machinist to be required to have a understanding of how computers function or the use of application software that goes along with them.

In this module we will start investigating computer use at more then an "operator" level.

It would not be uncommon in the machine shop for a Machinist to be expected to do minor maintenance and repair on normal machines, and in this fashion it has become important for the CAD/CAM/CNC specialist to do the same type things to one of our newest and most powerful tools, the computer.

Presentation Outline:

I. Demonstrate Use of Personal Computer
    A. Demonstrate use of computer hardware
        1. Describe and demonstrate the function and proper use of common computer components: (power switch, turbo switch, video monitor, keyboard, mouse, hard drive, floppy disk drive, printer & plotter, etc.)
        2. Describe and demonstrate proper computer use
            a. No food or drinks near computers
            b. No finger prints, or pen points on computer screens
            c. Proper cleaning of computer components to include:
                (1) Monitors
                (2) Keyboards
                (3) Mice
                (4) Disk drives
II. Describe and Identify Various Memory Types and Their Functions
    A. Read only memory "ROM"
    B. Random access memory "RAM"
    C. Hard disk
    D. Floppy disk: (5¼" DSDD, 5¼" DSHD, 3½" DSDD, 3½" DSHD)
        1. CD-Rom's
        2. Tape backups
III. Describe Main Computer Components and Their Application
    A. Motherboard
    B. Video card

    - C. Processor
    - D. Parallel ports
    - E. Co-Processor
    - F. Ram chips
    - G. Serial ports
    - H. Mice
    - I. Modems
    - J. Network cards
    - K. CD-Rom
- IV. Demonstrate Ability to Connect Basic Computer Components
    - A. Monitor
    - B. Mouse
    - C. Computer (central processing unit)
    - D. Keyboard
    - E. Printer
    - F. Modem
    - G. Network cards
    - H. CD-Rom

Practical Application:

Note to the Instructor: It would be wise to break the class down into groups. You may have some individuals in your class who are already familiar with computers, many students have their own computers at home, these individuals can act as group leaders.

If you have the computer parts listed above, use these to show the students what the different parts look like, and how to assemble them properly.

As an assigned project you can either have the students assemble a complete computer or a least show how to connect the major components listed in section IV.

Evaluation and/or Verification:

You may want to create a written test that covers this module. It might be wise to use an essay version. Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions

Next Lesson Assignment:

MASTER Technical Module (CNC-H2) dealing with using various operating systems.

CNC-H1-HO
Use Personal Computer
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this module the student will be able to:

- a. Demonstrate proper use of personal computers;
- b. Describe and identify various memory types and their functions;
- c. Describe and identify main computer components and their applications; and,
- d. Demonstrate ability to connect basic computer components.

Module Outline:

- I. Demonstrate Use of Personal Computer
  - A. Demonstrate use of computer hardware
    - 1. Describe and demonstrate the function and proper use of common computer components: (power switch, turbo switch, video monitor, keyboard, mouse, hard drive, floppy disk drive, printer & plotter, etc.)
    - 2. Describe and demonstrate proper computer use
      - a. No food or drinks near computers
      - b. No finger prints, or pen points on computer screens
      - c. Proper cleaning of computer components to include:
        - (1) Monitors
        - (2) Keyboards
        - (3) Mice
        - (4) Disk drives
- II. Describe and Identify Various Memory Types and Their Functions
  - A. Read only memory "ROM"
  - B. Random access memory "RAM"
  - C. Hard disk
  - D. Floppy disk: (5¼" DSDD, 5¼" DSHD, 3½" DSDD, 3½" DSHD)
    - 1. CD-Rom's
    - 2. Tape backups
- III. Describe Main Computer Components and Their Application
  - A. Motherboard
  - B. Video card
  - C. Processor
  - D. Parallel ports
  - E. Co-Processor
  - F. Ram chips
  - G. Serial ports

    H. Mice
    I. Modems
    J. Network cards
    K. CD-Rom
IV. Demonstrate Ability to Connect Basic Computer Components
    A. Monitor
    B. Mouse
    C. Computer (central processing unit)
    D. Keyboard
    E. Printer
    F. Modem
    G. Network cards
    H. CD-Rom

Name______________________ Date:____________________

CNC-H1
Use Personal Computer
Self-Assessment

Circle the letter preceding the correct answer.

1. The term "ROM" stands for?
   a. Random Only Memory
   b. Read Only Memory
   c. Read On Memory
   d. Random Outside Memory
   e. None of these

2. The term "RAM" stands for?
   a. Random Access Memory
   b. Read Another Memory
   c. Read Additional Memory
   d. Random Accessive Memory
   e. None of these

3. The term "hard disk" would be the same as the term?
   a. 3.5" Floppy disk
   b. 5.25" Floppy Disk
   c. Tape drive backup
   d. Hard Drive
   e. None of these

4. The 5.25" floppy DSDD standard disk holds _______ of information?
   a. 720K
   b. 1.2M
   c. 1.44M
   d. 360K
   e. None of these

5. The 5.25" floppy DSHD standard disk holds _______ of information?
   a. 720K
   b. 1.2M
   c. 1.44M
   d. 360K
   e. None of these

6. The 3.5" floppy DSDD standard disk holds _______ of information?
   a. 720K
   b. 1.2M
   c. 1.44M
   d. 360K
   e. None of these

7. The 3.5" floppy DSHD standard disk holds _______ of information?
   a. 720K
   b. 1.2M
   c. 1.44M
   d. 360K
   e. None of these

8. The amount of RAM that a computer has in it has an effect on the overall operating speed of the computer?
   a. True
   b. False

9. What is the function of the motherboard?

   ____

10. What is the function of the video card?

    ____

11. Describe various graphic standards?

    ____

12. What is the function of the main processor?

    ____

13. Describe various types of main processors?

    ____

14. What is the function of the co-processor?

    ____

15. What is the function of RAM?

____

16. Describe various RAM chip configurations/standards?

____

17. What is the function of the serial ports?

____

18. What is the function of the parallel ports?

____

19. What is the function of the mouse?

____

20. Describe various types of mice?

____

21. Describe the function of the keyboard?

____

22. Describe various standards of keyboards?

____

23. Describe various printers?

____

24. What is the function of a modem and how does it work?

____

25. What is the function of the network card and how does it work?

____

26. **What is the function of a CD-ROM?**

CNC-H2

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-H2

Subject: **Advanced CNC and CAM** **Time: 20 Hrs.**

Duty: **Use Verification and Communication Systems**
Task: Use Various Operating Systems

Objective(s):

Upon completion of this module the student will be able to:

a. Demonstrate a basic understanding of the common DOS commands;
b. Demonstrate a basic understanding of the common Windows commands;
c. Demonstrate a basic understanding of the common Windows NT commands; and,
d. Demonstrate a basic understanding of the common Windows 95 commands.

Instructional Materials:

MASTER Handout (CNC-H2-HO)
MASTER Self-Assessment

References:

Computer reference manual that has come with your system; and,
Basic computer books you may already have, or that are easily available in your area.

Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-A1 through CNC-A5	"Practice Safety"
CNC-B1 through CNC-B8	"Apply Mathematical Concepts"
CNC-C1 through CNC-C10	"Interpret Engineering Drawings and Control Documents"
CNC-D1 through CNC-D5	"Recognize Different Manufacturing Materials and Processes"
CNC-E1 through CNC-E6	"Measure/Inspect"
CNC-F1 through CNC-F8	"Perform Conventional Machining"
CNC-G1 through CNC-G4	"Perform Advanced Machining"
CNC-H1	"Use Personal Computer"

Introduction:

In using the computer, we must realize that there are different types of software that perform different tasks; two of the most common types are Operating Systems and Application Software.

Application software is that software which performs a specific set of tasks, examples of these tasks may be CAD/CAM, spreadsheets, word processors, or data bases. Application software creates our finished product in relationship to the computer operations we are using.

Another major type of software that is very important can be called an operating system. The Operating system (or system software) is the software that actually controls the computer; it creates the platform for application software to run on. The operating system can be compared to the foundation of a bridge; its design and construction has a direct effect as to what can be applied to the top of it.

It is very important to have a thorough understanding of these operating systems due to the fact that in today's modern environment many of the auxiliary functions are controlled by the operating system itself. Examples of functions controlled by operating system software include file management, printing capabilities, display settings, and networking operations.

As a CAD/CAM/CNC technician you will have to become very familiar with the use of not only CAD/CAM applications but also the use and maintenance of the computers you will be using. CAD/CAM technicians must be proficient in not only machining principles but also computer usage.

Presentation Outline:

I. Demonstrate Use of Basic DOS Commands
    A. Operate disk commands
        1. Format a floppy diskette
        2. Create boot disk (system disk)
        3. Change disk drives
    B. Operate view commands
        1. View file using DIR command and with pause (/p) and wide (/w) switches
        2. View directory using tree command
        3. View file using Dir command with:
            a. Filename and wildcards in place of extensions
            b. Extensions and wildcards in place of file names
            c. Filename and extension
    C. Create subdirectories and files

1. Make subdirectory
2. Identify and describe filename and extensions
3. Create filename and extension using DOS editor

D. Modify, move and copy files

1. Modify existing file using DOS editor
2. Explain path statements
3. Copy file to another location using:
   - a. Filename and extension
   - b. Wildcards
   - c. Wildcards and extensions in place of filename
   - d. Filename and wildcards in place of extensions
4. Delete or erase file using filename or extension
5. Move file using:
   - a. Filename and extensions
   - b. Wildcards
   - c. Wildcard and extensions in place of filename
   - d. Filename and wildcards in place of extensions
6. Copy file and directory using XCOPY command
7. Create backup diskette using DISKCOPY command
8. Change file name using RENAME command
9. Change disk name using LABEL command
10. Delete directory using REMOVE DIRECTORY command
11. Create and modify batch files

E. Set computer clock, date and time

1. Set computer clock using TIME command
2. Set computer calendar using DATE command

F. Perform disk maintenance

1. Optimize memory storage using CHKDSK /F and DEFRAG command
2. Evaluate memory using CHKDSK
3. Maintain memory disk using SCANDISK command
4. Describe utility packages used for disk maintenance

II. Demonstrate Use of Windows, Windows NT, and Windows 95 Commands

A. Manipulate program icons

1. Logging onto a computer system
2. Start windows
3. Describe program icons / desktop
4. Maximize and minimize program icons
5. Describe and maximize main program group

B. Use File Manager/ Windows Explorer functions

1. Open File Manager / Windows Explorer
2. Logging on (connecting) to a network system
3. Change drive using drive buttons
4. Pull down file selection using mouse
5. Tag file groups using mouse and Select key

        6. Tag various files using mouse and CTRL key
    C. Move, copy and change files in file menu
        1. Move file using mouse to drag and drop
        2. Copy file using mouse to drag and drop
        3. Delete file using mouse
        4. Change filename and extension using RENAME command
        5. Change properties of file including: Read Only, Archive, System, Hidden
    D. Maintain and print directories and files
        1. Start an application from File Manager using Run
        2. Start an application from File Manager using double click mouse method
        3. Print file using PRINT command
        4. Connect files to applications using the ASSOCIATE command
        5. Create directories (parent and child) using CREATE DIRECTORIES command
        6. Search for "lost" files using SEARCH command, filename, extension and wildcard
    E. Use disk menu utilities
        1. Pull down disk menu using mouse
        2. Copy disk using COPY DISK command
        3. Change disk label using LABEL DISK command
        4. Format disk using FORMAT command
        5. Create system disk using FORMAT command
        6. Change drive using SELECT DRIVE command
    F. Manipulate view menu commands
        1. View files by filename, extensions and wildcards
        2. Display files showing all file details and partial file details
        3. Sort files by name, type, size and date
    G. Exit File Manager/Windows Explorer
        1. Exit file manager by double clicking control menu box with mouse
        2. Exit file manager by choosing exit from file menu selection

III. Demonstrate Use of Macros in Windows and Windows NT Programs
    A. Use basic Windows command macros
        1. Get help using the help key (F1)
        2. Close current application window (ALT + F4)
        3. Close Program Manager and exit Windows program (ALT + F4, ENTER)
        4. Close the current document window (CTRL + F4)
        5. Change a DOS application from full-screen view to window and back to full screen (ALT + ENTER)
        6. From DOS application open Control menu in Windows program (ALT + SPACE BAR)
        7. Send copy of current full-screen view of DOS text to Clipboard

(PRINT SCREEN)

8. Send a copy of current window to Clipboard (ALT + PRINT SCREEN)

B. Switch task using Macros
    1. Bring up the Task List dialog box to display the list of the programs (CTRL + ESC)
    2. Cycle through the list of active tasks (ALT + TAB)
    3. Cycle through open windows and minimized programs (ALT + ESC)

C. Use menu and submenu commands and options
    1. Highlight the first item on a menu bar (ALT or F10)
    2. Open and close a menu (ALT + UNDERLINE CHARACTER)
    3. Open and close a submenu (UNDERLINE CHARACTER)
    4. Close a menu or submenu (ESC)
    5. Open the Control menu of the current application window (ALT + SPACE BAR)
    6. Open the Control menu of the current document window (ALT + HYPHEN)

D. Manipulate dialog box options
    1. Close and cancel a dialog box (ESC)
    2. Cycle forward through the options (TAB)
    3. Cycle backward through the options (SHIFT + TAB)
    4. Move to the first item in a list (HOME)
    5. Move to the last item in a list (END)
    6. Select all items in a list (CTRL + SLASH)
    7. Deselect all items in a list, except for the current selection (CTRL + BACKSLASH)
    8. Select the highlighted command button (ENTER)
    9. Toggle a highlighted check box (SPACE BAR)
    10. Choose option button and highlight item in a list (ARROW KEYS)
    11. Activate a command button containing an underlined character (ALT + UNDERLINED CHARACTER)
    12. Highlight an option containing an underlined character (ALT + UNDERLINED CHARACTER)
    13. Toggle a check-box item containing an underlined character (ALT + UNDERLINED CHARACTER)
    14. Select the option button containing an underlined character (ALT + UNDERLINED CHARACTER)
    15. Copy objects using (CTRL + C)
    16. Cut objects using (CTRL + X)
    17. Paste objects using (CTRL + V)

Practical Application:

I would suggest designing a hands on "project/test" that incorporates the operations listed above.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-H3) dealing with using computer communications systems.

CNC-H2-HO
Use Various Operating Systems
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this module the student will be able to:
- a. Demonstrate a basic understanding of the common DOS commands;
- b. Demonstrate a basic understanding of the common Windows commands;
- c. Demonstrate a basic understanding of the common Windows NT commands; and,
- d. Demonstrate a basic understanding of the common Windows 95 commands.

Module Outline:

- I. Demonstrate Use of Basic DOS Commands
  - A. Operate disk commands
    - 1. Format a floppy diskette
    - 2. Create boot disk (system disk)
    - 3. Change disk drives
  - B. Operate view commands
    - 1. View file using DIR command and with pause (/p) and wide (/w) switches
    - 2. View directory using tree command
    - 3. View file using Dir command with:
      - a. Filename and wildcards in place of extensions
      - b. Extensions and wildcards in place of file names
      - c. Filename and extension
  - C. Create subdirectories and files
    - 1. Make subdirectory
    - 2. Identify and describe filename and extensions
    - 3. Create filename and extension using DOS editor
  - D. Modify, move and copy files
    - 1. Modify existing file using DOS editor
    - 2. Explain path statements
    - 3. Copy file to another location using:
      - a. Filename and extension
      - b. Wildcards
      - c. Wildcards and extensions in place of filename
      - d. Filename and wildcards in place of extensions
    - 4. Delete or erase file using filename or extension
    - 5. Move file using:

a. Filename and extensions
b. Wildcards
c. Wildcard and extensions in place of filename
d. Filename and wildcards in place of extensions
6. Copy file and directory using XCOPY command
7. Create backup diskette using DISKCOPY command
8. Change file name using RENAME command
9. Change disk name using LABEL command
10. Delete directory using REMOVE DIRECTORY command
11. Create and modify batch files
E. Set computer clock, date and time
1. Set computer clock using TIME command
2. Set computer calendar using DATE command
F. Perform disk maintenance
1. Optimize memory storage using CHKDSK /F and DEFRAG command
2. Evaluate memory using CHKDSK
3. Maintain memory disk using SCANDISK command
4. Describe utility packages used for disk maintenance
II. Demonstrate Use of Windows, Windows NT, and Windows 95 Commands
A. Manipulate program icons
1. Logging onto a computer system
2. Start windows
3. Describe program icons / desktop
4. Maximize and minimize program icons
5. Describe and maximize main program group
B. Use File Manager/ Windows Explorer functions
1. Open File Manager / Windows Explorer
2. Logging on (connecting) to a network system
3. Change drive using drive buttons
4. Pull down file selection using mouse
5. Tag file groups using mouse and Select key
6. Tag various files using mouse and CTRL key
C. Move, copy and change files in file menu
1. Move file using mouse to drag and drop
2. Copy file using mouse to drag and drop
3. Delete file using mouse
4. Change filename and extension using RENAME command
5. Change properties of file including: Read Only, Archive, System, Hidden
D. Maintain and print directories and files
1. Start an application from File Manager using Run
2. Start an application from File Manager using double click mouse method
3. Print file using PRINT command

4. Connect files to applications using the ASSOCIATE command
5. Create directories (parent and child) using CREATE DIRECTORIES command
6. Search for "lost" files using SEARCH command, filename, extension and wildcard

E. Use disk menu utilities
   1. Pull down disk menu using mouse
   2. Copy disk using COPY DISK command
   3. Change disk label using LABEL DISK command
   4. Format disk using FORMAT command
   5. Create system disk using FORMAT command
   6. Change drive using SELECT DRIVE command

F. Manipulate view menu commands
   1. View files by filename, extensions and wildcards
   2. Display files showing all file details and partial file details
   3. Sort files by name, type, size and date

G. Exit File Manager/Windows Explorer
   1. Exit file manager by double clicking control menu box with mouse
   2. Exit file manager by choosing exit from file menu selection

III. Demonstrate Use of Macros in Windows and Windows NT Programs

A. Use basic Windows command macros
   1. Get help using the help key (F1)
   2. Close current application window (ALT + F4)
   3. Close Program Manager and exit Windows program (ALT + F4, ENTER)
   4. Close the current document window (CTRL + F4)
   5. Change a DOS application from full-screen view to window and back to full screen (ALT + ENTER)
   6. From DOS application open Control menu in Windows program (ALT + SPACE BAR)
   7. Send copy of current full-screen view of DOS text to Clipboard (PRINT SCREEN)
   8. Send a copy of current window to Clipboard (ALT + PRINT SCREEN)

B. Switch task using Macros
   1. Bring up the Task List dialog box to display the list of the programs (CTRL + ESC)
   2. Cycle through the list of active tasks (ALT + TAB)
   3. Cycle through open windows and minimized programs (ALT + ESC)

C. Use menu and submenu commands and options
   1. Highlight the first item on a menu bar (ALT or F10)
   2. Open and close a menu (ALT + UNDERLINE CHARACTER)
   3. Open and close a submenu (UNDERLINE CHARACTER)

4. Close a menu or submenu (ESC)
5. Open the Control menu of the current application window (ALT + SPACE BAR)
6. Open the Control menu of the current document window (ALT + HYPHEN)

D. Manipulate dialog box options

1. Close and cancel a dialog box (ESC)
2. Cycle forward through the options (TAB)
3. Cycle backward through the options (SHIFT + TAB)
4. Move to the first item in a list (HOME)
5. Move to the last item in a list (END)
6. Select all items in a list (CTRL + SLASH)
7. Deselect all items in a list, except for the current selection (CTRL + BACKSLASH)
8. Select the highlighted command button (ENTER)
9. Toggle a highlighted check box (SPACE BAR)
10. Choose option button and highlight item in a list (ARROW KEYS)
11. Activate a command button containing an underlined character (ALT + UNDERLINED CHARACTER)
12. Highlight an option containing an underlined character (ALT + UNDERLINED CHARACTER)
13. Toggle a check-box item containing an underlined character (ALT + UNDERLINED CHARACTER)
14. Select the option button containing an underlined character (ALT + UNDERLINED CHARACTER)
15. Copy objects using (CTRL + C)
16. Cut objects using (CTRL + X)
17. Paste objects using (CTRL + V)

Name____________________ Date:__________________

CNC-H2
Use Various Operating Systems
Self-Assessment

One of the tests that I use that gives the students practice is to create a subdirectory on the network drive. In this subdirectory I put:

1. Files that have duplicate file names but different file extensions.
2. Files that have different file names but duplicate file extensions.

In this exercise I am having the students demonstrate their ability to perform different operations using the computer.

You can perform this same exercise using DOS, Windows 3.X, Windows NT, or Windows 95.

I would recommend using as many different operating systems as your students may find in the industry of your area.

I would also recommend using both the File Manager and Explorer in Windows 95. Although many people feel that DOS is not a viable operating system I would recommend that you teach the student its use, many companies still use DOS, and in the event Windows doesn't work DOS can be used to repair many problems. Here is a list of some of the major tasks I recommend as a starting point this can be manipulated into various formats depending on the overall need of you specific group.

1. Start computer
2. Start operating system
3. Check computer for virus
4. Check computer clock for correct time
5. Check computer for correct date
6. Format floppy diskette
7. Label floppy diskette
8. Perform "scan disk operation"
9. Perform "defrag operation"
10. Log onto network
11. Create student subdirectory (use students name)
12. Open master directory
13. Copy files from master directory to student subdirectory
14. Create individual subdirectories under student subdirectory by filenames and extensions
15. Copy files to proper subdirectories relative to their file name and extensions (use various options to accomplish this task)
16. Verify proper copying of files
17. Remove files from main student subdirectory

18. Copy files from student subdirectories back to main student subdirectories
19. Remove files from student subdirectories
20. Remove empty student subdirectories
21. Use various options to view, and sort files
22. Rename various files

Notepad; WordPad

23. Open Notepad and/or WordPad and type in a brief description of student exercise
24. Use the copy, cut, and paste commands within a document
25. Open second copy of Notepad or WordPad
26. Use the copy, cut, and paste commands to transfer information from one document to another
27. Save document onto network drive
28. Save document onto student disk
29. Print document
30. Copy document into Clipboard
31. Paste document using Paint program
33. Save document using various graphic formats
34. Close Applications
35. Log off network
36. Close down computer system

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-H3

Subject: Advanced CNC and CAM **Time: 9 to 12 Hrs.**

Duty: **Use Verification and Communication Systems**
Task: Use Computer Communications Systems

Objective(s):

Upon completion of this module the student will be able to:
a. Identify various methods of communicating with CNC machines;
b. Identify the various terminologies that apply to communication standards; and,
c. Demonstrate the ability to connect and configure a communications link.

Instructional Materials:

MASTER Handout (CNC-H3-HO)

References:

Windows reference manual that has come with your system;
Basic computer books you may already have, or that are easily available in your area;
Most CAD/CAM packages have a built in communications section, (refer to software manual); and,
Reference manual that came with your CNC machine.

Student Preparation:

Note to Instructor: Please make sure that you have the proven communication parameters written down in a safe place before changing the existing settings. Also make sure that you have the books that cover the parameters that your specific machine uses, and that you know how to use it.

If this module is used properly it can be very beneficial to your students, if it is not handled properly it can cause a tremendous amount of damage. Please suggest to your students that they get permission from their supervisor before changing any communication parameters either at school or at work. Some company policies will only allow designated individuals to set up and modify these parameters.

Students should have previously completed the following Technical Modules:

CNC-A1 through CNC-A5	"Practice Safety"
CNC-B1 through CNC-B8	"Apply Mathematical Concepts"
CNC-C1 through CNC-C10	"Interpret Engineering Drawings and Control Documents"
CNC-D1 through CNC-D5	"Recognize Different Manufacturing Materials and Processes"
CNC-E1 through CNC-E6	"Measure/Inspect"
CNC-F1 through CNC-F8	"Perform Conventional Machining"
CNC-G1 through CNC-G4	"Perform Advanced Machining"
CNC-H1	"Use Personal Computer"
CNC-H2	"Use Various Operating Systems"

Introduction:

Whether we create a program by hand or use a sophisticated CAD/CAM package to generate an NC program, it is useless unless we can use it in the machine. It is very important to have the ability to send and receive programs using a computer and a machine controller. Although the days of paper and Mylar tape are behind us, the theory of communications remains the same. It is very important to understand the various terminologies and variables used in setting up communications parameters. Many companies, and individuals have no understanding of how to set up a Bi-directional communications network "link" to their machine tool and computer, this is very limiting if something goes wrong and the "original factory settings" get changed and no one knows how to correct them.

It is important to note that with a properly connected communication link it is very easy to send corrected "de-bugged" programs directly from the machine controller to the computer source in their corrected form. This ability saves a tremendous amount of time for the programmer.

The ability to communicate from the machine controller to the computer also allows us to perform routine back ups of NC programs that are stored in the controller for parts that are routinely machined. This protects us against accidental loss of programs which can amount to saving of thousands of dollars in lost programming time.

Presentation Outline:

I. Demonstrate Use of Computer Communication Systems
    A. Describe theory of communication as related to:
        1. CNC machines
        2. Computer networks
    B. Describe the common terminology used in communications
        1. Formats.

        - a. ASCII
        - b. EIA
        - c. BIN
        - d. ISO
    - 2. Serial communications connections:
        - a. Communications ports: COM1, COM2.....
            - (1) Various plug sizes
            - (2) Wiring diagram "pin outs"
    - 3. Communication speed "baud rate"
        - a. Why use higher and lower rates
        - b. What are the normal standards
        - c. What limits the baud rate
    - 4. Communication parity
        - a. Even
        - b. Odd
        - c. No parity
    - 5. Data and stop bit information
        - a. Numbers and settings
    - 6. Terminal emulation mode
        - a. Accessing machine controls from computer
- C. Punch and load tape medium
    - 1. Describe various standards of tape medium
    - 2. Punch tape to load program into machine
    - 3. Punch tape of edited program at machine
- D. Use electronic communications to load CNC programs
    - 1. Download and upload CNC programs using:
        - a. RS-232 interface
        - b. Communication section of CAD/CAM software
        - c. Windows software
        - d. Local area networks
        - e. Bi-directional communication (handshaking)
        - f. Direct Numerical Control
        - g. Distributive numerical control

Practical Application:

In this module I recommend splitting your class into teams. It is a good project to have the teams experiment with changing the settings on both the computer and the CNC machine.

Please make sure that you have the communication parameters written down in a safe place before changing the existing settings.

Evaluation and/or Verification:

I would advise creating a written test that covers the terminology and information that is relevant to the applications that will best suit your environment.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-H4) dealing with the use of verification systems.

CNC-H3-HO
Use Computer Communications Systems
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this module the student will be able to:
- a. Identify various methods of communicating with CNC machines;
- b. Identify the various terminologies that apply to communication standards; and,
- c. Demonstrate the ability to connect and configure a communications link.

Module Outline:

I. Demonstrate Use of Computer Communication Systems
  - A. Describe theory of communication as related to:
    - 1. CNC machines
    - 2. Computer networks
  - B. Describe the common terminology used in communications
    - 1. Formats:
      - a. ASCII
      - b. EIA
      - c. BIN
      - d. ISO
    - 2. Serial communications connections:
      - a. Communications ports: COM1, COM2.....
        - (1) Various plug sizes
        - (2) Wiring diagram "pin outs"
    - 3. Communication speed "baud rate"
      - a. Why use higher and lower rates
      - b. What are the normal standards
      - c. What limits the baud rate
    - 4. Communication parity
      - a. Even
      - b. Odd
      - c. No parity
    - 5. Data and stop bit information
      - a. Numbers and settings
    - 6. Terminal emulation mode
      - a. Accessing machine controls from computer
  - C. Punch and load tape medium
    - 1. Describe various standards of tape medium
    - 2. Punch tape to load program into machine

        3. Punch tape of edited program at machine

D. Use electronic communications to load CNC programs
    1. Download and upload CNC programs using:
        a. RS-232 interface
        b. Communication section of CAD/CAM software
        c. Windows software
        d. Local area networks
        e. Bi-directional communication (handshaking)
        f. Direct Numerical Control
        g. Distributive numerical control

CNC-H4

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-H4

Subject: **Advanced CNC and CAM** **Time: 30 Hrs.**

Duty: **Use Verification and Communication Systems**
Task: Use Verification Systems

Objective(s):

Upon completion of this module the student will be able to:

a. Identify various methods of verifying CNC programs;
b. Describe various settings used in preparing software for use;
c. Demonstrate ability to start CNC verification programs;
d. Perform operations required in configuring software for operation;
e. Demonstrate ability to apply various options required for model inspection; and,
f. Demonstrate ability to save various graphic images of completed models.

Instructional Materials:

MASTER Handout (CNC-H4-HO)

References:

Software manuals that come with both Vericut and N-See Software;
Help menus that are included in both software packages; and
CG-Tech instructional videos for its software "Vericut."

Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-A1 through CNC-A5	"Practice Safety"
CNC-B1 through CNC-B8	"Apply Mathematical Concepts"
CNC-C1 through CNC-C10	"Interpret Engineering Drawings and Control Documents"
CNC-D1 through CNC-D5	"Recognize Different Manufacturing Materials and Processes"
CNC-E1 through CNC-E6	"Measure/Inspect"
CNC-F1 through CNC-F8	"Perform Conventional Machining"
CNC-G1 through CNC-G4	"Perform Advanced Machining"
CNC-H1	"Use Personal Computer"

CNC-H2 "Use Various Operating Systems"
CNC-H3 "Use Computer Communications Systems"

Introduction:

With the advent of CAD/CAM it is possible to create very complex design and toolpaths for manufacturing. The ability to create these complex shapes has lent itself to the creation of very long programs as well as very expensive machined parts.

In our past we would create programs and then machine them in some form of softer material, possibly foam, wood, or wax to ensure our program was correct. This was better then trying our program in an expensive alloy, where if we did have an error we could possibly damage the material, cutting tools, and possibly even the machine tool.

In today's CAD/CAM technology we are no longer trapped in this type of "part verification." Included with most CAM software there is a toolpath verification section that displays the toolpath, represented in centerline form, or a solid representation of the generic data file, before it becomes machine code. The centerline verification becomes limited as the program becomes more complex, and we are aware that the "generic intermediate data" has to be post-processed into machine code.

It is obvious to us that the closer we can electronically verify a part to actual machining the better the result will be. We are also well aware that even though our intermediate data file is correct, mistakes in our post-processor can lead us into making very expensive and dangerous mistakes at the machine tool. It is very important for us to be able to verify the actual code that will be driving our machine tool. The ability to verify the actual machine code is available to us via the use of several different software applications created by various companies.

In addition to mistakes, we as programmers need more information when we are machining surface models, we do not want to guess that a part is safe to cut and then find out that we missed something that causes our whole part to be ruined possibly due to some in perfection in surface finish.

Even if we are very sure that our programs are correct it may take many hours, or even multiple work shifts to verify our part program using the method of cutting a "foam" model on the machine tool. With a reasonably fast computer and verification software we can "cut" a program in a verification software package in much less time then in the machine shop. This in itself represents a great time savings which of course is translated in saved machining expense.

This module will deal with the basic use of two of the software packages available as of this writing, one package is Vericut by CG-Tech Inc., and the other is N-SEE by Microcompatibles Inc. These are not the only software available to perform these applications, and the author is not making any claims in performance ratings of any form. These are the two packages that the author has available for use in the classes at San Diego City College in the Machine Technology Program. Both "Vericut" and "N-SEE" are copyrighted names, and software.

Both of the software packages we will address in this module come with sample programs that will allow the user to verify programs even if they do not have programs of their own.

Presentation Outline:

- I. Demonstrate Ability to Start CNC Verification Programs
  - A. Choose software for verification
    - 1. Describe verification process
    - 2. Describe traits of various software packages
    - 3. Explain applications of different software packages
    - 4. List and identify appropriate software packages based on:
      - a. Overall cost
      - b. Hardware requirements
      - c. Project requirements
      - d. Multi axes machining
      - e. Milling or turning
      - f. Operating system
    - 5. Describe and identify functions of file names and extensions
  - B. Start conversion process of toolpath for verification programs
    - 1. Describe conversion process from NC program to verification format
    - 2. Start PC
    - 3. Start conversion process
    - 4. Answer questions required in conversion process
- II. Program and Create CNC Verification Using "Vericut" by CG-Tech Inc.
  - A. Describe verification software
    - 1. Start software
    - 2. Describe menu structure
    - 3. Describe file extension formats and uses
    - 4. Describe various sections of display
    - 5. Describe information displayed by software
  - B. Program material definitions using stock functions
    - 1. Identify stock selection
    - 2. Define type of material stock
    - 3. Define length, width and height of stock
    - 4. Load stock files
    - 5. Rotate stock as needed
    - 6. Translate part home position to stock location

    7. Use accept and cancel options

C. Program view using view functions
    1. Identify view icon
    2. Rotate light source for different effects
    3. Change shade types and explain results
    4. Change view scale and explain results
    5. Rotate view as required
    6. Use accept, cancel, window, and preview options

D. Select color using color selection functions
    1. Identify color selection
    2. Select choices in color menu to include shading calculation for best results
    3. Use accept or cancel options, as required
    4. Describe and explain choices used in selection(s)

E. Program cutting set-up using cut functions
    1. Identify cut selection
    2. Select choices in cut set-up menu to:
        a. Set resolution and describe results
        b. Set cutter display and describe results
    3. Describe skip cut question and result
    4. Define path and filename of TP (APT) file

F. Program snap shots using snap shot functions
    1. Identify snap shot icon
    2. Select choices in snap shot menu to:
        a. Define file extension typically used for different applications
        b. Load existing snapshot "picture" file
        c. Save single snapshot file
        d. Control snap shot frequency
    3. Use auto save features, as required
    4. Use auto-error detection

G. Create cross section using cross section functions
    1. Identify cross section selections
    2. Select choices in cross section menu to include:
        a. Cross sectioning by plane numbers
        b. Cross sectioning by plane type
        c. Define options choice

H. Manipulate zoom functions
    1. Identify zoom selections
    2. Select choices in zoom menu to include: zoom mode, zoom resolution, scale factors

I. Program views of model using model functions
    1. Identify model selections
    2. Select choices in model menu to include:
        a. Translucent, reverse, display and cut models

J. Program tool path using tool path functions
  1. Identify tool path control selections
  2. Select choices in tool path menu to include:
    a. Tool path code type
    b. Machine type (milling or turning)
    c. Multi-axis
    d. Rotational choices

K. Program use of tools using tool control functions
  1. Identify tool control selections
  2. Select choices in tool control menu to include:
    a. Cutter, shank and holder selections

L. Program playback of program using playback functions
  1. Identify playback selections
  2. Select choices in playback menu to:
    a. Record verification session
    b. Play back verification session
  3. Describe benefits and drawbacks of recorded sessions

M. Select and manipulate user file functions
  1. Identify user file selections
  2. Define reasons for using user files
  3. Select choices in user file menu to:
    a. Define file extension for user file information
    b. Save user file information
    c. Load existing user file information

N. Create graphic image using shade copy functions
  1. Identify shade copy selections
  2. Select choices in shade copy menu to include:
    a. Type of shade copy
    b. Auto save and error functions
    c. Shading method
    d. Page orientation
    e. Using the TIFF format
    f. Output device
    g. Using the EPSF format
    h. Retrieving, converting various graphic file formats

O. Analyze measurement using x-caliper functions
  1. Identify x-caliper selection
  2. Select choices in x-caliper menu to measure:
    a. Distance and angles
    b. Points
    c. Stock thickness
    d. Air thickness
    e. Features

P. Execute use of holding devices using fixture functions
  1. Identify fixture selection

        - 2. Select choices in fixture menu to include:
            - a. Import fixtures
            - b. Define path and file to import
            - c. Describe plus and minus for fixture display
- III. Program CNC Verification Using Microcompatibles “N-SEE”
    - A. Select pull-down menu program
        - 1. Start program
        - 2. Select and describe which format to verify:
            - a. NC code
            - b. Intermediate files
            - c. Describe strengths and limitations of verifying each
    - B. Select options from file menu
        - 1. Select and answer appropriate questions:
            - a. NC program
            - b. Define measurement units
            - c. Set-up file
            - d. Translate NC code to RVP file if needed
            - e. Stock parameters
            - f. Define and describe upgrades available
            - g. Define tools
            - h. Choose preferred editor
            - i. Define machine controller
        - 2. Explain selected options
    - C. Select options from options menu
        - 1. Select and answer appropriate questions:
            - a. Pause process options
            - b. Axis rotation of model
            - c. Step size options
            - d. Light source rotation onto model
            - e. Rapid threshold feed rate
            - f. .STL file import for surface comparison
            - g. Spindle check for rotation and direction
            - h. Calculation for milling cycle time
            - i. Volume of material removed during machining
        - 2. Explain selected options
    - D. Describe model selection options
        - 1. Describe application, strengths and limitations of:
            - a. Preview
            - b. Verify
            - c. Turbo
    - E. Select examine selection options
        - 1. Select and use examine selection options to include:
            - a. X-section "cross section"
            - b. Color tools option
            - c. CMM inspection

        - d. Zoom functions
        - e. Measurement
- F. Select window selection options
    - 1. Select and use window selection options to include:
        - a. Statistics on/off
        - b. Maximize window
        - c. NC file display on/off
        - d. Tile command
        - e. Control display on/off
- G. Use help menu options
    - 1. Locate and describe help menu options to include:
        - a. Contents of help menu
        - b. Memory information for applications
        - c. Search for help on topic
        - d. Version call out for software
        - e. Instructions on how to use help menu
- H. Use control menu options
    - 1. Describe and use:
        - a. Control go
        - b. Control restart
- I. Exit software
    - 1. Exit software application

Practical Application:

In the beginning it may be a good idea to have the students work in teams so the will feel less intimidated. If the students don't have any completed programs available they can load the sample programs that come with the software.

As the students have programs of their own to verify I have them prove all their code using these software as a regular operating procedure. Besides using the software I have them save the graphic images to disk as well as have them print them out on a printer. Each one of these is turned in as part of any existing overall project.

Evaluation and/or Verification:

It may be helpful to create a written quiz that discusses the different files, and menu selections used in these software. It could also cover the overall process, and utilities that are offered in each software package.

Summary:

Review the main lesson points and answer student questions

Next Lesson Assignment:

MASTER Technical Module (CNC-H5) dealing with using the Internet.

CNC-H4-HO
Use Verification Systems
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this module the student will be able to:
- a. Identify various methods of verifying CNC programs;
- b. Describe various settings used in preparing software for use;
- c. Demonstrate ability to start CNC verification programs;
- d. Perform operations required in configuring software for operation;
- e. Demonstrate ability to apply various options required for model inspection; and,
- f. Demonstrate ability to save various graphic images of completed models.

Module Outline:

- I. Demonstrate Ability to Start CNC Verification Programs
  - A. Choose software for verification
    - 1. Describe verification process
    - 2. Describe traits of various software packages
    - 3. Explain applications of different software packages
    - 4. List and identify appropriate software packages based on:
      - a. Overall cost
      - b. Hardware requirements
      - c. Project requirements
      - d. Multi axes machining
      - e. Milling or turning
      - f. Operating system
    - 5. Describe and identify functions of file names and extensions
  - B. Start conversion process of toolpath for verification programs
    - 1. Describe conversion process from NC program to verification format
    - 2. Start PC
    - 3. Start conversion process
    - 4. Answer questions required in conversion process
- II. Program and Create CNC Verification Using "Vericut" by CG-Tech Inc.
  - A. Describe verification software
    - 1. Start software
    - 2. Describe menu structure
    - 3. Describe file extension formats and uses
    - 4. Describe various sections of display
    - 5. Describe information displayed by software

B. Program material definitions using stock functions
   1. Identify stock selection
   2. Define type of material stock
   3. Define length, width and height of stock
   4. Load stock files
   5. Rotate stock as needed
   6. Translate part home position to stock location
   7. Use accept and cancel options

C. Program view using view functions
   1. Identify view icon
   2. Rotate light source for different effects
   3. Change shade types and explain results
   4. Change view scale and explain results
   5. Rotate view as required
   6. Use accept, cancel, window, and preview options

D. Select color using color selection functions
   1. Identify color selection
   2. Select choices in color menu to include shading calculation for best results
   3. Use accept or cancel options, as required
   4. Describe and explain choices used in selection(s)

E. Program cutting set-up using cut functions
   1. Identify cut selection
   2. Select choices in cut set-up menu to:
      a. Set resolution and describe results
      b. Set cutter display and describe results
   3. Describe skip cut question and result
   4. Define path and filename of TP (APT) file

F. Program snap shots using snap shot functions
   1. Identify snap shot icon
   2. Select choices in snap shot menu to:
      a. Define file extension typically used for different applications
      b. Load existing snapshot "picture" file
      c. Save single snapshot file
      d. Control snap shot frequency
   3. Use auto save features, as required
   4. Use auto-error detection

G. Create cross section using cross section functions
   1. Identify cross section selections
   2. Select choices in cross section menu to include:
      a. Cross sectioning by plane numbers
      b. Cross sectioning by plane type
      c. Define options choice

H. Manipulate zoom functions

    1. Identify zoom selections
    2. Select choices in zoom menu to include: zoom mode, zoom resolution, scale factors

I. Program views of model using model functions
    1. Identify model selections
    2. Select choices in model menu to include:
        a. Translucent, reverse, display and cut models

J. Program tool path using tool path functions
    1. Identify tool path control selections
    2. Select choices in tool path menu to include:
        a. Tool path code type
        b. Machine type (milling or turning)
        c. Multi-axis
        d. Rotational choices

K. Program use of tools using tool control functions
    1. Identify tool control selections
    2. Select choices in tool control menu to include:
        a. Cutter, shank and holder selections

L. Program playback of program using playback functions
    1. Identify playback selections
    2. Select choices in playback menu to:
        a. Record verification session
        b. Play back verification session
    3. Describe benefits and drawbacks of recorded sessions

M. Select and manipulate user file functions
    1. Identify user file selections
    2. Define reasons for using user files
    3. Select choices in user file menu to:
        a. Define file extension for user file information
        b. Save user file information
        c. Load existing user file information

N. Create graphic image using shade copy functions
    1. Identify shade copy selections
    2. Select choices in shade copy menu to include:
        a. Type of shade copy
        b. Auto save and error functions
        c. Shading method
        d. Page orientation
        e. Using the TIFF format
        f. Output device
        g. Using the EPSF format
        h. Retrieving, converting various graphic file formats

O. Analyze measurement using x-caliper functions
    1. Identify x-caliper selection
    2. Select choices in x-caliper menu to measure:

        - a. Distance and angles
        - b. Points
        - c. Stock thickness
        - d. Air thickness
        - e. Features
  - P. Execute use of holding devices using fixture functions
    - 1. Identify fixture selection
    - 2. Select choices in fixture menu to include:
      - a. Import fixtures
      - b. Define path and file to import
      - c. Describe plus and minus for fixture display
- III. Program CNC Verification Using Microcompatibles "N-SEE"
  - A. Select pull-down menu program
    - 1. Start program
    - 2. Select and describe which format to verify:
      - a. NC code
      - b. Intermediate files
      - c. Describe strengths and limitations of verifying each
  - B. Select options from file menu
    - 1. Select and answer appropriate questions:
      - a. NC program
      - b. Define measurement units
      - c. Set-up file
      - d. Translate NC code to RVP file if needed
      - e. Stock parameters
      - f. Define and describe upgrades available
      - g. Define tools
      - h. Choose preferred editor
      - i. Define machine controller
    - 2. Explain selected options
  - C. Select options from options menu
    - 1. Select and answer appropriate questions:
      - a. Pause process options
      - b. Axis rotation of model
      - c. Step size options
      - d. Light source rotation onto model
      - e. Rapid threshold feed rate
      - f. .STL file import for surface comparison
      - g. Spindle check for rotation and direction
      - h. Calculation for milling cycle time
      - i. Volume of material removed during machining
    - 2. Explain selected options
  - D. Describe model selection options
    - 1. Describe application, strengths and limitations of:
      - a. Preview

    b. Verify
    c. Turbo

E. Select examine selection options
  1. Select and use examine selection options to include:
    a. X-section "cross section"
    b. Color tools option
    c. CMM inspection
    d. Zoom functions
    e. Measurement

F. Select window selection options
  1. Select and use window selection options to include:
    a. Statistics on/off
    b. Maximize window
    c. NC file display on/off
    d. Tile command
    e. Control display on/off

G. Use help menu options
  1. Locate and describe help menu options to include:
    a. Contents of help menu
    b. Memory information for applications
    c. Search for help on topic
    d. Version call out for software
    e. Instructions on how to use help menu

H. Use control menu options
  1. Describe and use:
    a. Control go
    b. Control restart

I. Exit software
  1. Exit software application

CNC-H5

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-H5

Subject: Advanced CNC and CAM **Time:** 18-21 Hrs.

Duty: Use Verification and Communication Systems
Task: Use the Internet

Objective(s):

Upon completion of this module the student will be able to:

a. Access and use modem connection;
b. Access and use the Internet;
c. Discuss and apply different aspects of the Internet;
d. Download files using the Internet;
e. Access various user groups; and,
f. Create basic web page using Netscape Navigator Gold.

Instructional Materials:

MASTER Handout (CNC-H5-HO)

References:

Computer books referencing the Internet
Internet resource online locations

Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-A1 through CNC-A5	"Practice Safety"
CNC-B1 through CNC-B8	"Apply Mathematical Concepts"
CNC-C1 through CNC-C10	"Interpret Engineering Drawings and Control Documents"
CNC-D1 through CNC-D5	"Recognize Different Manufacturing Materials and Processes"
CNC-E1 through CNC-E6	"Measure/Inspect"
CNC-F1 through CNC-F8	"Perform Conventional Machining"
CNC-G1 through CNC-G4	"Perform Advanced Machining"
CNC-H1	"Use Personal Computer"
CNC-H2	"Use Various Operating Systems"
CNC-H3	"Use Computer Communications Systems"
CNC-H4	"Use Verification Systems"

Introduction:

Although the Internet is not new it has gained a tremendous following over the last few years.

Manufacturing, along with other industries, has started to rely heavily on the Internet to advertise as well as transfer electronic information. Some examples of information that is transferred over the Internet can include drawings, price quotes, pictures of machine setups, and even NC code. There are many companies that have become as reliant on the Internet as they have their CNC machines and CAD/CAM software. This is a trend that will continue into the future.

As the CAD/CAM/CNC technician it may very well be your responsibility to use the Internet as a daily working tool. The ability to use the Internet as well as creating and updating a Web site for you company could become as common as creating programs for your company's machine tools.

Presentation Outline:

I. Access and Use Modem Connection
   A. Describe how modems communicate
   B. Describe various standards and settings used in communication
   C. Change modem and software settings as necessary
   D. Describe various software for modem use
II. Access and Use Internet
   A. Describe the history of Internet
   B. Describe theory and application of Internet
   C. Describe basic HTML use
   D. Discuss and apply different aspects of the Internet
      1. Web browsing (surfing)
      2. E-mail
      3. File transfer protocols
      4. Search engines
   E. Describe and use various web browsers
      1. Netscape Navigator
      2. Microsoft Internet Explorer
   F. Create basic web page using Netscape Navigator Gold
      1. Backgrounds
      2. Animated .GIF files
      3. Hyper Links
      4. Indexing Properties
         a. Tables
         b. Links
         c. Targets

5. Using .JPG Images
    a. Inserting images
    b. Resizing images
    c. Linking images
    d. Creating graphic images
    e. Graphic programs to manipulate images
6. Registering web sites with search engines

Practical Application:

The instructor should split the group into teams to make coordination easier. You may have individuals in the group who already know a great deal about both the Internet and web page design; these individuals can be very helpful as group leaders. The instructor should have students do a research project using the Internet as a sole information source for a project. Have them find information on CAD/CAM companies, CNC machines, common trade magazines, and job possibilities.

If you have the capabilities, have them create a basic web page which includes as many items from the course as possible for another project.

As another project, have them download information from the Internet to a local machine or floppy disk.

As another project have them get involved with some different user groups where they can post questions to the manufacturing community at an international level.

Evaluation and/or Verification:

The hands on project should show whether the students have an understanding of the Internet. It may also be wise to create a written test that defines the common terms used for the Internet.

Summary:

Review the main lesson points and answer student questions

Next Lesson Assignment:

MASTER Technical Module (CNC-I1) dealing with understanding CAD/CAM programs.

CNC-H5-HO
Use the Internet
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this module the student will be able to:

a. Access and use modem connection;
b. Access and use the Internet;
c. Discuss and apply different aspects of the Internet;
d. Download files using the Internet;
e. Access various user groups; and,
f. Create basic web page using Netscape Navigator Gold.

Module Outline:

I. Access and Use Modem Connection
  A. Describe how modems communicate
  B. Describe various standards and settings used in communication
  C. Change modem and software settings as necessary
  D. Describe various software for modem use
II. Access and Use Internet
  A. Describe the history of Internet
  B. Describe theory and application of Internet
  C. Describe basic HTML use
  D. Discuss and apply different aspects of the Internet
    1. Web browsing (surfing)
    2. E-mail
    3. File transfer protocols
    4. Search engines
  E. Describe and use various web browsers
    1. Netscape Navigator
    2. Microsoft Internet Explorer
  F. Create basic web page using Netscape Navigator Gold
    1. Backgrounds
    2. Animated .GIF files
    3. Hyper Links
    4. Indexing Properties
      a. Tables
      b. Links
      c. Targets
    5. Using .JPG Images
      a. Inserting images
      b. Resizing images

    - c. Linking images
    - d. Creating graphic images
    - e. Graphic programs to manipulate images
6. Registering web sites with search engines

CNC MACHINIST .... **programs, edits, sets up, and operates CNC lathes, mills and grinders to perform machining operations necessary to produce workpieces to referenced engineering standards.**

	Duties	← Tasks →												
A	Practice Safety	A-1 Follow safety manuals and all safety regulations/ requirements	A-2 Use protective equipment	A-3 Follow safe operating procedures for hand and machine tools	A-4 Maintain a clean and safe work environment	A-5 MSDS/ control chemical hazards								
B	Apply Mathematical Concepts	B-1 Perform basic arithmetic functions	B-2 Convert fractions/ decimals	B-3 Convert Metric/ English measurements	B-4 Perform basic algebraic operations	B-5 Use practical geometry	B-6 Understand basic trigonometry	B-7 Calculate speeds and feeds for machining	B-8 Use coordinate systems					
C	Interpret Engineering Drawings and Control Documents	C-1 Identify basic layout of drawings	C-2 Identify basic types of drawings	C-3 Review blueprint notes and dimensions	C-4 List the purpose of each type of drawing	C-5 Verify drawing elements	C-6 Practice Geometric Dimensioning and Tolerancing (GD&T)	C-7 Analyze bill of materials (BOM)	C-8 Describe the relationship of engineering drawings to planning	C-9 Understand and use quality systems	C-10 Verify standard requirements			
D	Recognize Different Manufacturing Materials and Processes	D-1 Identify materials with desired properties	D-2 Identify materials and processes to produce a part	D-3 Describe the heat treating process	D-4 Test metal samples for hardness	D-5 Understand welding operations								
E	Measure/ Inspect	E-1 Understand metrology terms	E-2 Select measurement tools	E-3 Measure with hand held instruments	E-4 Eliminate measurement variables	E-5 Measure/ inspect using surface plate and accessories	E-6 Inspect using stationary equipment							
F	Perform Conventional Machining	F-1 Prepare and plan for machining operations	F-2 Use hand tools	F-3 Operate power saws	F-4 Operate drill presses	F-5 Operate vertical milling machines	F-6 Operate horizontal milling machines	F-7 Operate metal cutting lathes	F-8 Operate grinding/ abrasive machines					
G	Perform Advanced Machining	G-1 Understand CNC basics	G-2 Program CNC machines	G-3 Operate CNC machining centers (mills)	G-4 Operate CNC turning centers (lathes)									
H	Use Verification and Communication Systems	H-1 Use personal computer	H-2 Use various operating systems	H-3 Use computer communications systems	H-4 Use verification systems	H-5 Use the Internet								
I	Program Using CAM System	I-1 Understand CAD/ CAM programs	I-2 Manipulate CAD functions	I-3 Process simple tool-path data	I-4 Create advanced surface models	I-5 Process complex tool-path functions								

CNC-I1

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-I1

Subject: **Advanced CNC and CAM** **Time: 3 Hrs.**

Duty: **Program Using CAM System**
Task: Understand CAD/CAM Programs

Objective(s):

Upon completion of this module the student will be able to:
a. Describe various CAD/CAM software;
b. Describe differences between CAD/CAM;
c. Discuss various software packages; and,
d. Describe various requirements for CAD/CAM software.

Instructional Materials:

MASTER Handout (CNC-I1-HO)

References:

There are many books available that discuss CAD/CAM, but most of them are very software company specific.

Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-A1 through CNC-A5	"Practice Safety"
CNC-B1 through CNC-B8	"Apply Mathematical Concepts"
CNC-C1 through CNC-C10	"Interpret Engineering Drawings and Control Documents"
CNC-D1 through CNC-D5	"Recognize Different Manufacturing Materials and Processes"
CNC-E1 through CNC-E6	"Measure/Inspect"
CNC-F1 through CNC-F8	"Perform Conventional Machining"
CNC-G1 through CNC-G4	"Perform Advanced Machining"
CNC-H1 through CNC-H5	"Use Verification and Communication Systems"

Introduction:

This Module is designed to be an information module.

One of the most misunderstood computer applications is the area of CAD/CAM. The average individual has no idea what CAD/CAM even does. Many people who have a basic understanding of CAD/CAM automatically associate the term with creating drawings. Most people have no idea that the term CAD/CAM actually can cover a broad range of topics. It is important that before we venture into the area of CAD/CAM, we have an overall understanding of what some of the possibilities are.

The overall objective of this module is to allow the Instructor to present the possibilities of CAD/CAM to the students so that students will have a better understanding of the various applications of our field.

I have listed a few common software in the following outline only as a sampling of possible discussion areas.

Please be certain to include the information that this is only a small sampling of the overall available discussion topics.

Presentation Outline:

I. Demonstrate Understanding of CAD/CAM Programs
    A. Explain CAD/CAM programs
        1. Define Computer Aided Design (CAD)
        2. Define Computer Aided Manufacturing (CAM)
        3. Describe common applications of CAD and CAM
        4. Discuss common CAD packages to include:
            a. AutoCAD
            b. CadKey
            c. Micro Station
        5. Discuss Common CAM packages to include:
            a. MasterCam
            b. SurfCam
            c. SmartCam
        6. Describe common applications of CAD package design areas
            a. Architectural
            b. Electronics
            c. Mechanical
    B. Discuss various design modeling databases
        1. Wire Frame
        2. Surface Models
        3. Solid Models

II. Describe Various Abilities of CAD/CAM
    A. Discuss common applications of CAM software for:
        1. Vertical Machining applications
        2. Turning applications
        3. Grinding applications
        4. E.D.M. Applications
    B. Discuss benefits of using:
        1. Wire Frame
        2. Surface Models
        3. Solid Models
    C. Discuss flexibility and increased production for application of:
        1. CAD for Design
        2. CAM for Manufacturing

III. Describe Various Requirements for CAD/CAM Software
    A. Computer hardware
    B. Computer operating systems
    C. Education/Training

Practical Application:

After the Instructor has discussed what CAD/CAM is, it would be beneficial if the instructor could show some examples of the software in operation. A short demonstration of available software would give the students an overall example of what each software type "CAD" vs. "CAM" does.

After the demonstration, start a discussion with the group about applications they have seen, how they could apply CAD/CAM at their company, or how they could expand it's uses to benefit productivity.

Evaluation and/or Verification:

This module is written mainly for informational purposes.

If the Instructor feels a test is necessary, he could create a simple multiple choice test to cover the main points as it would apply to the group's needs.

Summary:

Review the main lesson points and answer student questions

Next Lesson Assignment:

MASTER Technical Module (CNC-I2) dealing with manipulation of CAD functions.

CNC-I1-HO
Understand CAD/CAM Programs
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this module the student will be able to:

- a. Describe various CAD/CAM software;
- b. Describe differences between CAD/CAM;
- c. Discuss various software packages; and,
- d. Describe various requirements for CAD/CAM software.

Module Outline:

- I. Demonstrate Understanding of CAD/CAM Programs
  - A. Explain CAD/CAM programs
    - 1. Define Computer Aided Design (CAD)
    - 2. Define Computer Aided Manufacturing (CAM)
    - 3. Describe common applications of CAD and CAM
    - 4. Discuss common CAD packages to include:
      - a. AutoCAD
      - b. CadKey
      - c. Micro Station
    - 5. Discuss Common CAM packages to include:
      - a. MasterCam
      - b. SurfCam
      - c. SmartCam
    - 6. Describe common applications of CAD package design areas
      - a. Architectural
      - b. Electronics
      - c. Mechanical
  - B. Discuss various design modeling databases
    - 1. Wire Frame
    - 2. Surface Models
    - 3. Solid Models
- II. Describe Various Abilities of CAD/CAM
  - A. Discuss common applications of CAM software for:
    - 1. Vertical Machining applications
    - 2. Turning applications
    - 3. Grinding applications
    - 4. E.D.M. Applications
  - B. Discuss benefits of using:
    - 1. Wire Frame
    - 2. Surface Models

        3. Solid Models
    C. Discuss flexibility and increased production for application of:
        1. CAD for Design
        2. CAM for Manufacturing

III. Describe Various Requirements for CAD/CAM Software
    A. Computer hardware
    B. Computer operating systems
    C. Education/Training

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-I2

Subject: **Advanced CNC and CAM** **Time: 30-50 Hrs.**

Duty: **Program Using CAM System**
Task: Manipulate CAD Functions

Objective(s):

Upon completion of this module the student will be able to:

a. Demonstrate the correct use of CAD/CAM software to generate basic 2-dimensional shapes; and,
b. Demonstrate the correct use of CAD/CAM software to generate basic 3-dimensional shapes.

Instructional Materials:

MASTER Handout (CNC-I2-HO)

References:

There are not many books available that discuss CAD/CAM with an emphasis on CAM, but normally there is an instructional manual that comes with the purchase of the software packages.

In the area of CAD there are many after market books available. Please check to see what is available for your software.

If you are using either MasterCam or SurfCam, there is now an aftermarket book for each. To get more information about these books contact:

Dr. Su-Chen Jonathan Lin
Scholars International Publishing Corporation
2675 Georgetown Blvd.
Ann Arbor, MI. 48105
Telephone: (313) 930-0813
Fax. Number: (313) 741-1927

Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-A1 through CNC-A5	"Practice Safety"
CNC-B1 through CNC-B8	"Apply Mathematical Concepts"

CNC-C1 through CNC-C10	"Interpret Engineering Drawings and Control Documents"
CNC-D1 through CNC-D5	"Recognize Different Manufacturing Materials and Processes"
CNC-E1 through CNC-E6	"Measure/Inspect"
CNC-F1 through CNC-F8	"Perform Conventional Machining"
CNC-G1 through CNC-G4	"Perform Advanced Machining"
CNC-H1 through CNC-H5	"Use Verification and Communication Systems"
CNC-I1	"Understand CAD/CAM Programs"

Introduction:

Part I:

In this module we will discuss the actual use of CAD/CAM software to create electronic images. For those students who are using MasterCam you will notice that the information listed in the outline below relates directly to the menu commands in MasterCam.

For those of you who are not using MasterCam, your software will have menu selections that, although they are not the exactly the same as the ones listed in the outline below, they will have similar commands to perform the same type operations.

Also for anyone using either MasterCam or SurfCam, I would recommend the book listed in the resource section of this outline written by Dr. Jonathan Lin.

For those of you who are using some other company's software, there should be some type of written information that will allow you to become familiar with the basic operations listed below.

Part II:

There is no doubt that in the long term CAD/CAM saves a tremendous amount of time, and is much more flexible than paper drawings. Having made this statement it is important to note that the process of using CAD/CAM software to generate designs is a process that can be very time consuming. There is no automatic design creation that I am aware of as of this writing. Using computers to create designs is like everything else: it takes practice to become good at it.

The outline listed below covers the basic geometric elements used in creating designs. This outline only discusses wire frame geometry creation; it does not discuss either surface modeling or solid modeling. Wire frame design, although not as sophisticated as surfaces and solid modeling, encompasses the building blocks that will be used later on in more advanced CAD designs.

In CNC/CAM, we are interested in CAD as a method of generating the necessary geometric entities that will allow us to guide a cutting tool along a defined boundary or a set of boundaries to create the necessary information that will control the actions of a CNC machine tool to create a machined part to given specifications.

When we have completed the CAD component, we are only getting started. We then have to complete the CAM component as required to move onto the CNC machine.

In the overall process of CAD/CAM/CNC, the CAD section can often consume a vast majority of the time used in completion of a manufactured object. The ability to create a quality design in a short amount of time is definitely an important part of the complete process.

Presentation Outline:

I. Access CAD Program Options
    A. Explain the configuration of CAD/CAM software
        1. Explain configuration of:
            a File and path names
            b. Installation, including DOS and Windows
            c. Configure software
            d. Interaction of files between each other
        2. Describe the "flow" process of CAD/CAM
    B. Access CAD software
        1. Access CAD software, including AutoCAD and CadKey, to:
            a. Create basic 2-dimensional designs
            b. Create 3-dimension designs
            c. Dimension designs to be used as drawings
            d. Create title blocks and borders for prints
            e. Print drawings
            f. Plot drawings
            g. Create general and local drawing notes and tolerances
        2. Describe various file conversion formats
        3. Import and export designs using conversions, including:
            a. IGES
            b. CADL
            c. DXF
            d. STL
    C. Access CAM software
        1. Load existing design

2. Import and export design files from various file format standards, including:
   a. IGES
   b. DXF
   c. CADL
   d. STL
3. Save design files to “permanent” memory
4. Access CAD section of CAM software to create
   a. Create basic 2-dimensional designs
   b. Create 3-dimension designs
   c. Dimension designs to be used as drawings
   d. Create title blocks and borders for prints
   e. Print drawings
   f. Plot drawings
   g. Create general and local drawing notes and tolerances

II. Create Basic Geometric Entities
  A. Create basic geometric entities, including:
    1. Points
    2. Fillets
    3. Lines
    4. Splines
    5. Arcs
    6. Chamfers
    7. Circles
    8. Letters including various machinable fonts
  B. Dimension completed designs to create detailed drawings
  C. Transform geometric entities using CAD commands
    1. Transform geometric entities, including:
      a. Mirror entities
      b. Rotate entities
      c. Scale complete entities using single scale option
      d. Translate using move and copy options
      e. Offset single and grouped geometric entities
      f. Use group function to effect multiple entities simultaneously
      g. Use result function to effect group movements
  D. Set menu selections to:
    1. View planes
    2. Construction planes
    3. Color choices
  E. Use Delete command:
    1. Use Delete commands, including:
      a. Chained and duplicate entities
      b. Exclusive entities (only)
      c. Inclusive entities (all)

        d. Enclosed in window
        e. Intersecting window
- F. Execute screen and display functions
    1. Use screen and display functions to:
        a. List screen statistics
        b. Display entity endpoints
        c. Clear group and result color designation
        d. Change colors of entities
        e. Display window
        f. Un-zoom display
        g. Change levels of entities
        h. Fit entities to screen
        i. Set various view ports
        j. Refresh screen
        k. Change views
        l. Set active levels
        m. Change entities between levels
        m. Set screen center "pan"
        n. Initialize display "clear"
        o. Rotate display
- G. Use analyze function
    1. Use analyze function to interpret:
        a. Point descriptions
        b. Single entity information
        c. Locations of entities
        d. Distance between points
        e. Area calculations
        f. Calculation of angles

Practical Application:

For those of you that are using the Jonathan Lin book it is recommended that you complete the first 8 chapters of the book. Concern yourself with the CAD design for this module only.

It is also suggested that the Instructor interject some basic designs that they may get from local companies, this will give the students the experience of working on real drawings.

For those of you who will not be using the Lin book, most CAD/CAM software comes with a basic instruction book that may include basic designs. In addition, as stated above, the Instructor may add some basic drawings that would be used by local companies as an addition to the designs provided in the instructional books.

Evaluation and/or Verification:

A combination of written and hands-on testing should be used to establish the proficiency of the students.

For the written portion of the test a multiple choice test is recommended. Jonathan Lin's book has tests at the end of each chapter. These can be used as sample tests.

For the hands on testing, all students should create the same design and record their time. The time is then used to generate their grade for the hands on portion of the test. To tabulate a student's overall grade, written test time with the student's hands on test time are averaged.

Summary:

Review the main lesson points and answer student questions

Next Lesson Assignment:

MASTER Technical Module (CNC-I3) dealing with processing simple tool-path data.

CNC-I2-HO
Manipulate CAD Functions
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this module the student will be able to:

- a. Demonstrate the correct use of CAD/CAM software to generate basic 2-dimensional shapes; and,
- b. Demonstrate the correct use of CAD/CAM software to generate basic 3-dimensional shapes.

Module Outline:

- I. Access CAD Program Options
  - A. Explain the configuration of CAD/CAM software
    - 1. Explain configuration of:
      - a File and path names
      - b. Installation, including DOS and Windows
      - c. Configure software
      - d. Interaction of files between each other
    - 2. Describe the "flow" process of CAD/CAM
  - B. Access CAD software
    - 1. Access CAD software, including AutoCAD and CadKey, to:
      - a. Create basic 2-dimensional designs
      - b. Create 3-dimension designs
      - c. Dimension designs to be used as drawings
      - d. Create title blocks and borders for prints
      - e. Print drawings
      - f. Plot drawings
      - g. Create general and local drawing notes and tolerances
    - 2. Describe various file conversion formats
    - 3. Import and export designs using conversions, including:
      - a. IGES
      - b. CADL
      - c. DXF
      - d. STL
  - C. Access CAM software
    - 1. Load existing design
    - 2. Import and export design files from various file format standards, including:
      - a. IGES
      - b. DXF
      - c. CADL

      d. STL
    3. Save design files to “permanent” memory
    4. Access CAD section of CAM software to create
      a. Create basic 2-dimensional designs
      b. Create 3-dimension designs
      c. Dimension designs to be used as drawings
      d. Create title blocks and borders for prints
      e. Print drawings
      f. Plot drawings
      g. Create general and local drawing notes and tolerances
II. Create Basic Geometric Entities
  A. Create basic geometric entities, including:
    1. Points
    2. Fillets
    3. Lines
    4. Splines
    5. Arcs
    6. Chamfers
    7. Circles
    8. Letters including various machinable fonts
  B. Dimension completed designs to create detailed drawings
  C. Transform geometric entities using CAD commands
    1. Transform geometric entities, including:
      a. Mirror entities
      b. Rotate entities
      c. Scale complete entities using single scale option
      d. Translate using move and copy options
      e. Offset single and grouped geometric entities
      f. Use group function to effect multiple entities simultaneously
      g. Use result function to effect group movements
  D. Set menu selections to:
    1. View planes
    2. Construction planes
    3. Color choices
  E. Use Delete command:
    1. Use Delete commands, including:
      a. Chained and duplicate entities
      b. Exclusive entities (only)
      c. Inclusive entities (all)
      d. Enclosed in window
      e. Intersecting window
  F. Execute screen and display functions
    1. Use screen and display functions to:
      a. List screen statistics

        - b. Display entity endpoints
        - c. Clear group and result color designation
        - d. Change colors of entities
        - e. Display window
        - f. Un-zoom display
        - g. Change levels of entities
        - h. Fit entities to screen
        - i. Set various view ports
        - j. Refresh screen
        - k. Change views
        - l. Set active levels
        - m. Change entities between levels
        - m. Set screen center "pan"
        - n. Initialize display "clear"
        - o. Rotate display
- G. Use analyze function
    - 1. Use analyze function to interpret:
        - a. Point descriptions
        - b. Single entity information
        - c. Locations of entities
        - d. Distance between points
        - e. Area calculations
        - f. Calculation of angles

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-I3

Subject: **Advanced CNC and CAM** **Time: 20-30 Hrs.**

Duty: **Program Using CAM System**
Task: Process Simple Toolpath Data

Objective(s):

Upon completion of this module the student will be able to:

a. Properly identify various parts of CNC program generation;
b. Demonstrate the use of the post-processor and co-processor for intermediate CNC data;
c. Perform editing of CNC programs using various software; and
d. Perform verification of completed toolpaths.

Instructional Materials:

MASTER Handout (CNC-I3-HO)

References:

There are not many books available that discuss CAD/CAM with an emphasis on CAM, but normally there is an instructional manual that comes with the purchase of the software packages.

In the area of CAD there are many after market books available. Please check to see what is available for your software.

If you are using either MasterCam or SurfCam, there is now an aftermarket book for each. To get more information about these books contact:

Dr. Su-Chen Jonathan Lin
Scholars International Publishing Corporation
2675 Georgetown Blvd.
Ann Arbor, MI. 48105
Telephone: (313) 930-0813
Fax. Number: (313) 741-1927

Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-A1 through CNC-A5 "Practice Safety"

CNC-B1 through CNC-B8	"Apply Mathematical Concepts"
CNC-C1 through CNC-C10	"Interpret Engineering Drawings and Control Documents"
CNC-D1 through CNC-D5	"Recognize Different Manufacturing Materials and Processes"
CNC-E1 through CNC-E6	"Measure/Inspect"
CNC-F1 through CNC-F8	"Perform Conventional Machining"
CNC-G1 through CNC-G4	"Perform Advanced Machining"
CNC-H1 through CNC-H5	"Use Verification and Communication Systems"
CNC-I1	"Understand CAD/CAM Programs"
CNC-I2	"Manipulate CAD Functions"

Introduction:

Computer Aided Manufacturing (CAM) software has changed the way in which we generate CNC code more dramatically then any previous invention since the pocket calculator.

In the past we have had to generate programs using a tedious character by character process. With the advent of CAM software, which uses a graphic interface, we are free to be much more creative in both design and manufacturing of machined objects.

One benefit of CAM software is that it's use has removed much of the need of the technician to continually perform both simple and advanced mathematical equations. It is very easy to use these software to generate code to machine objects that would not be possible to create without the assistance of the computer and CAD/CAM software applications.

The proper use of CAM has allowed a much larger group of people to work in the field of creating CNC programs to "drive" various machine tools.

It is important to note that learning how to use a CAM package does not make the user a machinist, nor does the software know how to machine any objects. It is a tremendous benefit to all if the operator of the CAD/CAM software has a good understanding of general machining to include CNC.

Presentation Outline:

I. Generate Numerical (NC) Code
    A. Generate NC code to access:
        1. Turning center "lathe"
        2. Vertical machining center "mill"
II. Generate Basic Vertical Machining Code

- A. Generate basic vertical machining code for operations, including:
    - 1. Outside and inside contours
    - 2. Pocketing operations
        - a. Islands
        - b. Multiple "Z" level islands
    - 3. Drilling, reaming, spot drilling, tapping operations

III. Program Lathe or Turning Operations

- A. Use CAD section to create geometric designs
- B. Create lathe tools as required
- C. Create toolpath information to rough and finish
    - 1. Create toolpath information to rough and finish during:
        - a. Turning operations
        - b. Facing operations
        - c. Grooving operations
        - d. Internal boring operations / external boring operations
        - e. Internal and external threading
- D. Edit toolpath data files
    - 1. View and edit tool path data files, including:
        - a. Display centerline tool path
        - b. Calculate time to machine
        - c. Filter tool path data to reduce size and time
        - d. Change feed rates and compare results
        - e. Edit tool path data to change possible variables
        - f. Define tool selections and operating parameters
        - g. Define materials to be machined
        - h. Create set-up document
    - 2. Verify toolpaths by cutting part as solid model
    - 3. Verify toolpaths by "backplotting" toolpaths
- E. Process Tool Path Data to Numerical Control Code
    - 1. Select post processing file relative to machine tool being used
    - 2. Execute post processing function
    - 3. Edit numerical control program if needed
- F. Describe and Execute Post-Processor or Co-processor Functions
    - 1. Describe post-processor and co-processor functions
    - 2. Run processors

Practical Application:

For those of you that are using the Jonathan Lin book I would recommend completing the first 8 chapters of the book to generate the CAD sections. Then complete the toolpaths for those designs. In the back section of the book there is a lathe section to be used to get a better understanding of the lathe section of the CAM software.

Please make sure to take your time and get a very good understanding of how the basic toolpath commands work. This will not only help you later in the surface modules, but you will more than likely have to use these commands as a large portion of your responsibilities.

Please do not skip over the pockets, contours, and drilling operations so you can advance to the more advanced modules. Approximately 85% of all machined pieces fall into this category.

It is suggested that the Instructor interject some basic designs that they may get from local companies. This will give the students the experience of working on real designs.

For those of you who will not be using the Lin book, most CAD/CAM software comes with a basic instruction book that may include basic designs. In addition, as stated above, add some basic drawings that would be used by local companies as an addition to the designs provided in the instructional books.

Evaluation and/or Verification:

Use a combination of written and hands on tests to establish the proficiency of the students. For the written portion of the test, create a multiple choice test. Jonathan Lin's book has tests at the end of each chapter. These can be used as sample tests.

For the hands on testing, have all the students create the same design and create the required toolpaths needed to machine the associated objects. Also have them machine the parts as a solid model in the verification section of the software. Record all the students' time for the various sections.

Use the time to generate their grade for the hands on portion of the test. To tabulate their overall grade, average their written test time with their hands on test time.

Summary:

Review the main lesson points and answer student questions

Next Lesson Assignment:

MASTER Technical Module (CNC-I-4) dealing with creating advanced surface models.

CNC-I3-HO
Process Simple Toolpath Data
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this module the student will be able to:
- a. Properly identify various parts of CNC program generation;
- b. Demonstrate the use of the post-processor and co-processor for intermediate CNC data;
- c. Perform editing of CNC programs using various software; and
- d. Perform verification of completed toolpaths.

Module Outline:

- I. Generate Numerical (NC) Code
  - A. Generate NC code to access:
    - 1. Turning center "lathe"
    - 2. Vertical machining center "mill"
- II. Generate Basic Vertical Machining Code
  - A. Generate basic vertical machining code for operations, including:
    - 1. Outside and inside contours
    - 2. Pocketing operations
      - a. Islands
      - b. Multiple "Z" level islands
    - 3. Drilling, reaming, spot drilling, tapping operations
- III. Program Lathe or Turning Operations
  - A. Use CAD section to create geometric designs
  - B. Create lathe tools as required
  - C. Create toolpath information to rough and finish
    - 1. Create toolpath information to rough and finish during:
      - a. Turning operations
      - b. Facing operations
      - c. Grooving operations
      - d. Internal boring operations / external boring operations
      - e. Internal and external threading
  - D. Edit toolpath data files
    - 1. View and edit tool path data files, including:
      - a. Display centerline tool path
      - b. Calculate time to machine
      - c. Filter tool path data to reduce size and time
      - d. Change feed rates and compare results
      - e. Edit tool path data to change possible variables
      - f. Define tool selections and operating parameters

        g. Define materials to be machined
        h. Create set-up document
    2. Verify toolpaths by cutting part as solid model
    3. Verify toolpaths by "backplotting" toolpaths

E. Process Tool Path Data to Numerical Control Code
    1. Select post processing file relative to machine tool being used
    2. Execute post processing function
    3. Edit numerical control program if needed

F. Describe and Execute Post-Processor or Co-processor Functions
    1. Describe post-processor and co-processor functions
    2. Run processors

CNC-I4

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-I4

Subject: **Advanced CNC and CAM** **Time: 30-50 Hrs.**

Duty: **Program Using CAM System**
Task: Create Advanced Surface Models

Objective(s):

Upon completion of this module the student will be able to demonstrate the correct use of CAD/CAM software to create 2- and 3-dimensional geometric shapes and surface models.

Instructional Materials:

MASTER Handout (CNC-I4-HO)

References:

As stated in earlier modules, there are unfortunately not many books available that discuss CAD/CAM with an emphasis on CAM. Normally there is an instructional manual that comes with the purchase of the software packages.

If you are using either MasterCam or SurfCam, there is now an aftermarket book for each. To get more information about these books contact:
Dr. Su-Chen Jonathan Lin
Scholars International Publishing Corporation
2675 Georgetown Blvd.
Ann Arbor, MI. 48105
Telephone: (313) 930-0813
Fax. Number: (313) 741-1927

Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-A1 through CNC-A5	"Practice Safety"
CNC-B1 through CNC-B8	"Apply Mathematical Concepts"
CNC-C1 through CNC-C10	"Interpret Engineering Drawings and Control Documents"
CNC-D1 through CNC-D5	"Recognize Different Manufacturing Materials and Processes"
CNC-E1 through CNC-E6	"Measure/Inspect"

CNC-F1 through CNC-F8	“Perform Conventional Machining”
CNC-G1 through CNC-G4	“Perform Advanced Machining”
CNC-H1 through CNC-H5	“Use Verification and Communication Systems”
CNC-I1	“Understand CAD/CAM Programs”
CNC-I2	“Manipulate CAD Functions”
CNC-I3	“Process Simple Toolpath Data”

Introduction:

Part I:

This module is written with an emphasis on the software called MasterCam, which is created by the company ,C.N.C. Software Inc., version 6.12. As many of us know, software as well as our technology, changes very rapidly. By the time you review this module, much of the nomenclature may have changed. Please check your version number to see what changes have been made.

Some of the surface names used with the software SurfCam, which is created by the company SurfCam, Inc., are included in italics in the presentation outline. As with MasterCam, the names of these surface entities may have changed by the time you read this.

Please note that we are not trying to misrepresent any of the software. If you have any specific questions please contact the specific software manufacture.

This module can be looked at as an extension to the previous CAD/CAM module, which emphasizes CAD.

Part II:

As we have seen in the previous CAD module, the proper application of CAD/CAM software allows us a tremendous amount of flexibility in our designs. As we look at more sophisticated designs, we find that defining the wireframe or “outline” no longer gives us the amount of information needed to describe our design properly. Examples that would create a need for surface modeling are very easily seen in the mold making industry. It is important to note that even though this industry is not as large as the general CAD marketplace, this area is where the higher rates of pay are found.

As we create designs using surface models, we can truly start to appreciate the power of the computer used in conjunction with CAD/CAM software. It is important to remember that we are creating these designs so we will be able to generate advanced toolpaths for the CNC machines.

Presentation Outline:

- I. Create Advanced Designs with CAD Section of CAD/CAM Program
  - A. Create advanced geometric surfaces
    - 1. Create advanced geometric surfaces to include:
      - a. Lofted / *Cross Section*
      - b. Blend
      - c. Swept / *Drive Curve*
      - d. Trim
      - e. Coons / *4-Curve*
      - f. Draft
      - g. Offset
      - h. Nurb Surface
      - i. Fillet
      - j. Parametric Surface
  - B. Edit geometric entities
    - 1. Modify and edit advanced geometric surfaces to include:
      - a. Trimming
      - b. Breaking
      - c. Joining
      - d. Fillet
  - C. Edit advanced geometric surfaces
    - 1. Modify and edit advanced geometric surfaces to include:
      - a. Control points of nurbs
      - b. Conversion to nurbs entity
      - c. Extend entities
      - d. Drag entities
      - e. Edit entities
    - 2. Change cutter offset side
    - 3. Change cutting directions
    - 4. Turn surface normal arrows on and off
    - 5. Decompose composite surfaces
    - 6. Twist vectors of parametric surface
    - 7. Create polygons on surface
    - 8. Align surface normals
    - 9. Trim surfaces
    - 10. Untrim trimmed surfaces
  - D. Transform geometric entities using CAD commands
    - 1. Scale X, Y, and Z at possible separate ratios
  - E. Execute screen and display functions
    - 1. Use screen and display functions to:
      - a. Change surface density
      - b. Shade surface models
      - c. Blank and unblank entities

Practical Application:

For those of you that are using the Jonathan Lin book I would recommend completing the chapters of the book that deal with the generation of surface models.

It is suggested that the Instructor interject some designs that they may get from local companies. This will give the students the experience of working on real designs. Some of the designs that make good examples for the use of surface modeling are found in the mold making industry.

For those of you who will not be using the Lin book, most CAD/CAM software comes with a basic instruction book that may include surface models.

Evaluation and/or Verification :

Use a combination of written and hands on testing to establish the proficiency of the students.

For the written portion of the test, create a multiple choice test. Jonathan Lin's book has tests at the end of each chapter. These can be used as sample tests.

For the hands on testing, have all the students create the same design and record their time. Use the time to generate their grade for the hands on portion of the test. To tabulate their overall grade, average their written test time with their hands on test time.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (CNC-I5) dealing with processing complex toolpath functions.

CNC-I4-HO
Create Advanced Surface Models
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this module the student will be able to demonstrate the correct use of CAD/CAM software to create 2- and 3-dimensional geometric shapes and surface models.

Module Outline:

I. Create Advanced Designs with CAD Section of CAD/CAM Program
  A. Create advanced geometric surfaces
    1. Create advanced geometric surfaces to include:
      a. Lofted / *Cross Section*
      b. Blend
      c. Swept / *Drive Curve*
      d. Trim
      e. Coons / *4-Curve*
      f. Draft
      g. Offset
      h. Nurb Surface
      i. Fillet
      j. Parametric Surface
  B. Edit geometric entities
    1. Modify and edit advanced geometric surfaces to include:
      a. Trimming
      b. Breaking
      c. Joining
      d. Fillet
  C. Edit advanced geometric surfaces
    1. Modify and edit advanced geometric surfaces to include:
      a. Control points of nurbs
      b. Conversion to nurbs entity
      c. Extend entities
      d. Drag entities
      e. Edit entities
    2. Change cutter offset side
    3. Change cutting directions
    4. Turn surface normal arrows on and off
    5. Decompose composite surfaces
    6. Twist vectors of parametric surface
    7. Create polygons on surface

        8. Align surface normals
        9. Trim surfaces
        10. Untrim trimmed surfaces

D. Transform geometric entities using CAD commands
    1. Scale X, Y, and Z at possible separate ratios

E. Execute screen and display functions
    1. Use screen and display functions to:
        a. Change surface density
        b. Shade surface models
        c. Blank and unblank entities

ADVANCED CNC and CAM SERIES

MASTER Technical Module No. CNC-I5

Subject: **Advanced CNC and CAM** **Time: 35-50 Hrs.**

Duty: **Program Using CAM System**
Task: Process Complex Toolpath Functions

Objective(s):

Upon completion of this module the student will be able to:

1. Demonstrate an understanding of the use of single surface machining;
2. Demonstrate an understanding of the use of multiple surface machining;
3. Demonstrate an understanding of the use of multiple tool planes and multi-axis machining; and,
4. Digitize existing objects to create new toolpaths.

Instructional Materials:

MASTER Handout (CNC-I5-HO)

References:

As stated in earlier modules, there are unfortunately not many books available that discuss CAD/CAM with an emphasis on CAM. Normally there is an instructional manual that comes with the purchase of the software packages.

If you are using either MasterCam or SurfCam, there is now an aftermarket book for each. To receive more information about these books contact:
Dr. Su-Chen Jonathan Lin
Scholars International Publishing Corporation
2675 Georgetown Blvd.
Ann Arbor, MI. 48105
Telephone: (313) 930-0813
Fax. Number: (313) 741-1927

Student Preparation:

Students should have previously completed the following Technical Modules:

CNC-A1 through CNC-A5	"Practice Safety"
CNC-B1 through CNC-B8	"Apply Mathematical Concepts"

CNC-C1 through CNC-C10	"Interpret Engineering Drawings and Control Documents"
CNC-D1 through CNC-D5	"Recognize Different Manufacturing Materials and Processes"
CNC-E1 through CNC-E6	"Measure/Inspect"
CNC-F1 through CNC-F8	"Perform Conventional Machining"
CNC-G1 through CNC-G4	"Perform Advanced Machining"
CNC-H1 through CNC-H5	"Use Verification and Communication Systems"
CNC-I1	"Understand CAD/CAM Programs"
CNC-I2	"Manipulate CAD Functions"
CNC-I3	"Process Simple Toolpath Data"
CNC-I4	"Create Advanced Surface Models"

Introduction:

Part I:

This module is not written with an emphasis on any specific software. I am more familiar with the software package, MasterCam, which is created by the company, C.N.C. Software Inc., version 6.12. As many of us know, software as well as our technology, changes very rapidly. By the time you review this module, much of the nomenclature may have changed. Please check your version number to see what changes have been made.

Both MasterCam and SurfCam, created by Surfware, Inc., are CAD/CAM software which is used for both CAD and CAM.

Please note that we are not trying to misrepresent any of the software. If you have any specific questions, please contact the software manufacture for more information.

This module can be looked at as an extension to the previous CAD/CAM module which emphasizes basic CAM.

Most software will have similar type operations. They may call the operations different names but more then likely they will accomplish the same type operations.

Part II:

As we have seen in the previous CAM module, the proper application of CAD/CAM software allows us a tremendous amount of flexibility in our designs as well as toolpaths. As we looked at more sophisticated designs, we found that defining the wireframe or "outline" no longer gave us the amount of information needed to describe our design properly. Examples that would create a need for surface machining are very easily seen in the mold making industry. It is important to note that even though this industry is not as large as the general CAM marketplace, this area is where the higher rates of pay are found.

As we create designs using surface models, we could truly start to appreciate the power of the computer used in conjunction with CAD/CAM software. It is important to remember that we created these designs so we could generate advanced toolpaths for the CNC machines.

As with the CAD modeling, in the earlier module (I4), we created toolpaths using wire frame designs. In this section we will work on surface machining which, as of this writing, is one of the most advanced methods of generating complex toolpaths.

Many of the toolpaths that we can create using surfacing cannot be created without the use of the computer coupled with CAD/CAM software. Those toolpaths that could be created without the use of CAD/CAM would take a tremendous amount of time and energy.

The use of CAD/CAM and surface toolpaths has allowed a much larger section of the population to accomplish, in a very short time period, the creation of programs that they would not be able to consider otherwise.

Many companies have been able to increase their level of technology to include the design and manufacturing of sophisticated shapes that the "wireframe" models would not be able to achieve.

As I have stated in the CAD module that covers surfacing, this marketplace is not as large as the "wireframe" marketplace but it is much more specialized. It pays higher wage rates to those who can use the technology, and is very challenging.

Presentation Outline:

I. Process Tool Path Data
  A. Generate advanced vertical machining code
    1. Generate code for three axis surface machining to include:
      a. Single surface machining,
        1) Create roughing toolpaths
        2) Create finishing toolpaths
      b. Multiple surface machining
        1) Create roughing toolpaths
        2) Create finishing toolpaths
    2. Generate code for four and five-axis surface machining to include:
      a. Single surface machining

            1) Create roughing toolpaths
            2) Create finishing toolpaths
        b. Multiple surface machining
            1) Create roughing toolpaths
            2) Create finishing toolpaths

B. Import and machine scanned data
    1. Import and machine three-dimensional data
        a. Collect data points using C.M.M.
        b. Collect data using vertical machining center and digitizing probe
        c. Convert scanned data into usable geometric entities
        d. Create appropriate surface types from wireframes
        e. Generate numerical control programs using surface models

C. Verify toolpaths
    1. Verify multi-surface toolpaths
    2. Verify 4th and 5th axis machine code

D. Describe and execute post-processor or co-processor functions
    1. Edit processors for 4th and 5th axis machining
    2. Process intermediate files into NC code

Practical Application:

For those of you that are using the Jonathan Lin book I would recommend completing the chapters of the book that deal with the generation of surface models toolpaths.

It is suggested that the Instructor interject some designs that they may get from local companies. This will give the students the experience of working on real designs. Some of the designs that make good examples for the use of surface modeling are found in the mold making industry.

The digitizing experiments, although not an actual part of the CAD/CAM software applications, allow us to capture data using a very non-traditional method. This data allows us to create surface models, and then toolpaths from existing actual objects. These experiments can only be accomplished if the user has access to the necessary equipment to capture the data needed.

Evaluation and/or Verification:

Use a combination of written and hands on tests to establish the proficiency of the students.

For the written portion of the test, create a multiple choice test. Jonathan Lin's book has tests at the end of each chapter. These can be used as sample tests.

For the hands on testing, have all the student's create the same design and create the required toolpaths needed to machine the associated objects. You may also have them machine the parts as a solid model in the verification section of the software. Use the time to generate their grade for the hands on a portion of the test. To tabulate their overall grade, average their written test time with their hands on test time.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

CNC-I5-HO
Process Complex Toolpath Functions
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this module the student will be able to:

1. Demonstrate an understanding of the use of single surface machining;
2. Demonstrate an understanding of the use of multiple surface machining;
3. Demonstrate an understanding of the use of multiple tool planes and multi-axis machining; and,
4. Digitize existing objects to create new toolpaths.

Module Outline:

I. Process Tool Path Data
    A. Generate advanced vertical machining code
        1. Generate code for three axis surface machining to include:
            a. Single surface machining,
                1) Create roughing toolpaths
                2) Create finishing toolpaths
            b. Multiple surface machining
                1) Create roughing toolpaths
                2) Create finishing toolpaths
        2. Generate code for four and five-axis surface machining to include:
            a. Single surface machining
                1) Create roughing toolpaths
                2) Create finishing toolpaths
            b. Multiple surface machining
                1) Create roughing toolpaths
                2) Create finishing toolpaths
    B. Import and machine scanned data
        1. Import and machine three-dimensional data
            a. Collect data points using C.M.M.
            b. Collect data using vertical machining center and digitizing probe
            c. Convert scanned data into usable geometric entities
            d. Create appropriate surface types from wireframes
            e. Generate numerical control programs using surface models
    C. Verify toolpaths
        1. Verify multi-surface toolpaths

    2. Verify 4th and 5th axis machine code

D. Describe and execute post-processor or co-processor functions

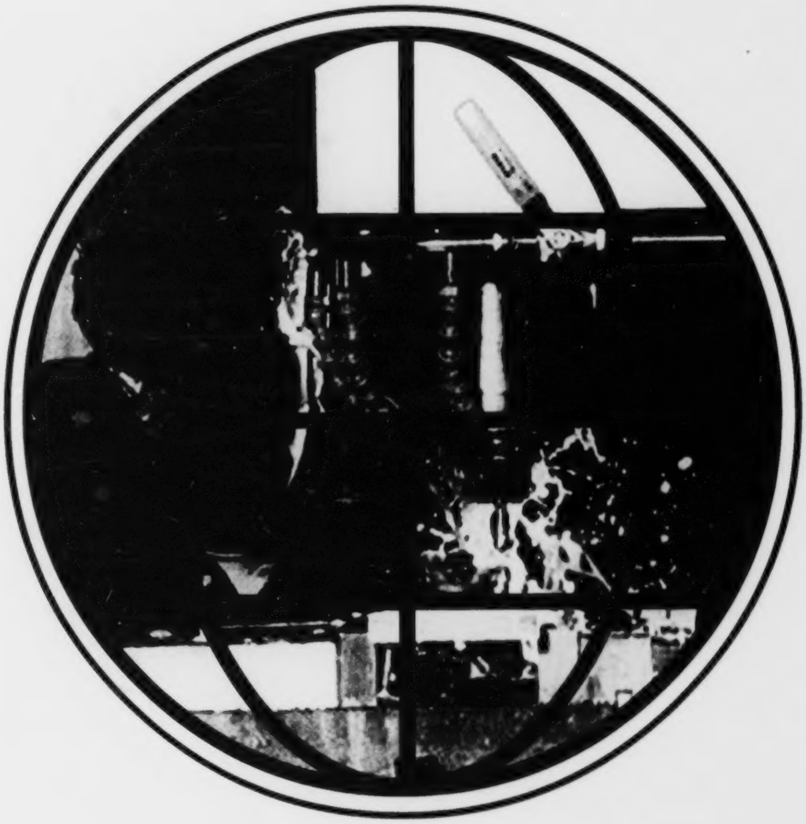
    1. Edit processors for 4th and 5th axis machining
    2. Process intermediate files into NC code

MASTER

MACHINE TOOL ADVANCED SKILLS TECHNOLOGY EDUCATIONAL RESOURCES

a consortium of educators and industry

EDUCATIONAL RESOURCES
FOR THE
MACHINE TOOL INDUSTRY



Advanced CNC and CAM Series
STUDENT LABORATORY MANUAL

Supported by the National Science Foundation's Advanced Technological Education Program

MACHINE TOOL ADVANCED SKILLS TECHNOLOGY EDUCATIONAL RESOURCES

MASTER

a consortium of educators and industry

EDUCATIONAL RESOURCES
FOR THE
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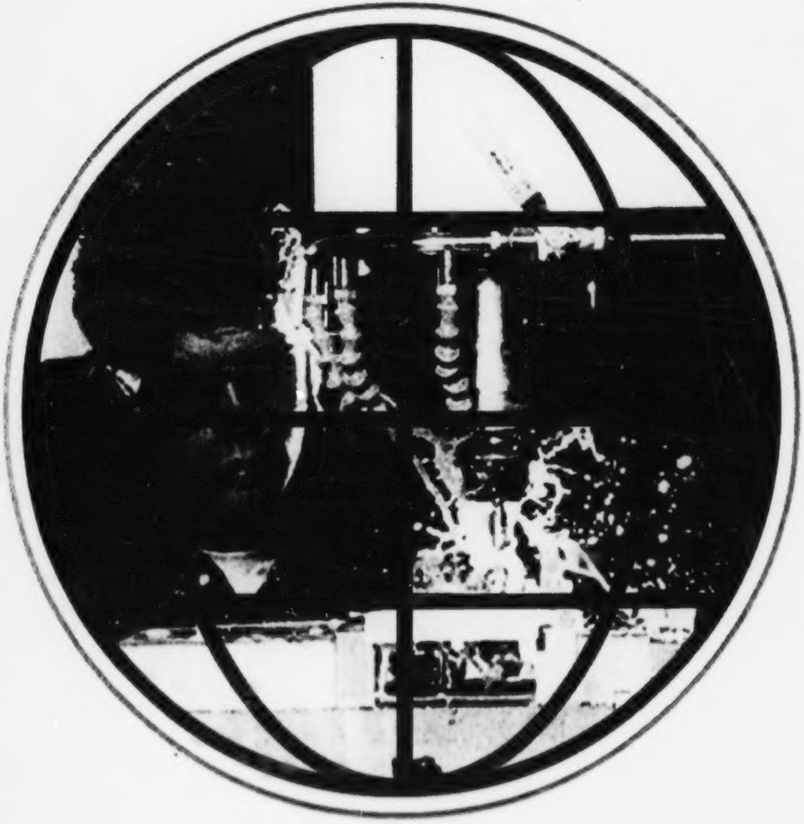

Advanced CNC and CAM Series

STUDENT LABORATORY MANUAL

Supported by the National Science Foundation's Advanced Technological Education Program

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National Science Foundation
Advanced Technological
Education Program

"Any opinions, findings, and conclusions or recommendations
expressed in this material are those of the author(s) and do
not necessarily reflect the views of the Foundation."

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This project was made possible by the cooperation and direct support of the following organizations:

National Science Foundation - Division of Undergraduate Education
MASTER Consortia of Employers and Educators

MASTER has built upon the foundation which was laid by the Machine Tool Advanced Skills Technology (MAST) Program. The MAST Program was supported by the U.S. Department of Education - Office of Vocational and Adult Education. Without this prior support MASTER could not have reached the level of quality and quantity that is contained in these project deliverables.

MASTER DEVELOPMENT CENTERS

Augusta Technical Institute - Central Florida Community College - Itawamba Community College - Moraine Valley Community College - San Diego City College (CACT) - Springfield Technical Community College - Texas State Technical College

INDUSTRIES

AB Lasers - AIRCAP/MTD - ALCOA - American Saw - AMOCO Performance Products - Automatic Switch Company - Bell Helicopter - Bowen Tool - Brunner - Chrysler Corp. - Chrysler Technologies - Conveyor Plus - Darr Caterpillar - Davis Technologies - Delta International - Devon - D. J. Plastics - Eaton Leonard - EBTEC - Electro-Motive - Emergency One - Eureka - Foster Mold - GeoDiamond/Smith International - Greenfield Industries - Hunter Douglas - Industrial Laser - ITT Engineered Valve - Kaiser Aluminum - Krueger International. - Laser Fare - Laser Services - Lockheed Martin - McDonnell Douglas - Mercury Tool - NASSCO - NutraSweet - Rapistan DEMAG - Reed Tool - ROHR, International - Searle - Solar Turbine - Southwest Fabricators - Smith & Wesson - Standard Refrigeration - Super Sagless - Taylor Guitars - Tecumseh - Teledyne Ryan - Thermal Ceramics - Thomas Lighting - FMC, United Defense - United Technologies Hamilton Standard

COLLEGE AFFILIATES

Aiken Technical College - Bevil Center for Advanced Manufacturing Technology - Chicago Manufacturing Technology Extension Center - Great Lakes Manufacturing Technology Center - Indiana Vocational Technical College - Milwaukee Area Technical College - Okaloosa-Walton Community College - Piedmont Technical College - Pueblo Community College - Salt Lake Community College - Spokane Community College - Texas State Technical Colleges at Harlington, Marshall, Sweetwater

FEDERAL LABS

Jet Propulsion Lab - Lawrence Livermore National Laboratory - L.B.J. Space Center (NASA) - Los Alamos Laboratory - Oak Ridge National Laboratory - Sandia National Laboratory - Several National Institute of Standards and Technology Centers (NIST) - Tank Automotive Research and Development Center (TARDEC) - Wright Laboratories

SECONDARY SCHOOLS

Aiken Career Center - Chicopee Comprehensive High School - Community High School (Moraine, IL) - Connally ISD - Consolidated High School - Evans High - Greenwood Vocational School - Hoover Sr. High - Killeen ISD - LaVega ISD - Lincoln Sr. High - Marlin ISD - Midway ISD - Moraine Area Career Center - Morse Sr. High - Point Lamar Sr. High -

Pontotoc Ridge Area Vocational Center - Putnam Vocational High School - San Diego Sr. High - Tupelo-Lee Vocational Center - Waco ISD - Westfield Vocational High School

ASSOCIATIONS

American Vocational Association (AVA) - Center for Occupational Research and Development (CORD) - CIM in Higher Education (CIMHE) - Heart of Texas Tech-Prep - Midwest (Michigan) Manufacturing Technology Center (MMTC) - National Coalition For Advanced Manufacturing (NACFAM) - National Coalition of Advanced Technology Centers (NCATC) - National Skills Standards Pilot Programs - National Tooling and Machining Association (NTMA) - New York Manufacturing Extension Partnership (NYMEP) - Precision Metalforming Association (PMA) - Society of Manufacturing Engineers (SME) - Southeast Manufacturing Technology Center (SMTC)

MASTER PROJECT EVALUATORS

Dr. James Hales, East Tennessee State University and William Ruxton, formerly with the National Tooling and Machine Association (NTMA)

NATIONAL ADVISORY COUNCIL MEMBERS

The National Advisory Council has provided input and guidance into the project since the beginning. Without their contributions, MASTER could not have been nearly as successful as it has been. Much appreciation and thanks go to each of the members of this committee from the project team.

Dr. Hugh Rogers-Dean of Technology-Central Florida Community College
Dr. Don Clark-Professor Emeritus-Texas A&M University
Dr. Don Edwards-Department of Management-Baylor University
Dr. Jon Botsford-Vice President for Technology-Pueblo Community College
Mr. Robert Swanson-Administrator of Human Resources-Bell Helicopter, TEXTRON
Mr. Jack Peck-Vice President of Manufacturing-Mercury Tool & Die
Mr. Don Hancock-Superintendent-Connally ISD

SPECIAL RECOGNITION

Dr. Hugh Rogers recognized the need for this project, developed the baseline concepts and methodology, and pulled together industrial and academic partners from across the nation into a solid consortium. Special thanks and singular congratulations go to Dr. Rogers for his extraordinary efforts in this endeavor.

Dr. Don Pierson served as the Principal Investigator for the first two years of MASTER. His input and guidance of the project during the formative years was of tremendous value to the project team. Special thanks and best wishes go to Dr. Pierson during his retirement and all his worldly travels.

All findings and deliverables resulting from MASTER are primarily based upon information provided by the above companies, schools and labs. We sincerely thank key personnel within these organizations for their commitment and dedication to this project. Including the national survey, more than 2,800 other companies and organizations participated in this project. We commend their efforts in our combined attempt to reach some common ground in precision manufacturing skills standards and curriculum development.

MASTER DEVELOPMENT CENTER, SAN DIEGO, CA
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San Diego City College

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Manufacturing in the San Diego Region

Manufacturing represents a major sector of the San Diego economy, accounting for almost one out of every four dollars (24%) of San Diego's gross regional product. The county is currently home to approximately 3,500 manufacturers employing roughly 110,000 San Diegans. During the first half of the 1990s, manufacturing in San Diego was hard hit by the downturn in military and defense spending which accompanied the end of the cold war. Many of the region's largest aerospace contractors rapidly downsized or moved their plants out of state, leaving a large supplier base that needed to modernize its manufacturing processes and convert to commercial markets. Rapid recovery of manufacturing in the region has been driven by San Diego's high tech research and development sectors in electronics, telecommunications, software, advanced materials, biotechnology, and medical instrumentation.

San Diego City College and its Center for Applied Competitive Technologies (CACT)

San Diego City College is an urban, minority institution, serving a large population of students from immigrant, disadvantaged, and low income households. In 1990, the College saw an opportunity to modernize its technical programs and improve the employment outlook for many of its students by agreeing to host one of the State of California's eight new regional manufacturing extension centers, the Centers for Applied Competitive Technologies (CACTs). The advanced technology centers were designed to assist local companies to modernize their manufacturing processes and convert from defense to newly emerging, technology-based commercial markets. This strategic partnership between the College and its resident CACT has proven to be highly successful. In developing the programs and lab facilities to serve the needs of regional manufacturing companies, the San Diego CACT and City College have simultaneously modernized the manufacturing and machine technology credit offerings of the College, thereby providing a well-trained, technically competent workforce for industry and enhancing career opportunities for students.

Development Team

- **Project Director:** Joan A. Stepsis, Ph.D., Dean/Director of the CACT-SD, served as programmatic manager and academic coordinator for the MASTER project.
- **Subject Matter Expert:** John C. Bollinger, Assoc. Prof. of Machine Technology, had programmatic responsibility for developing skill standards and course/program materials for the Advanced CNC and CAM component of the MASTER project. Professor Bollinger also served as the lead instructor for the MASTER instructional pilot for his specialty area.
- **Subject Matter Expert:** Douglas R. Welch, Assoc. Prof. of Manufacturing, had programmatic responsibility for developing skill standards and course/program materials for the Automated Equipment Technology (AET) and Machine Tool Integration (CIM) component of the MASTER project. Professor Welch also served as lead instructor for the MASTER instructional pilot for his specialty area.

Introduction:
STUDENT LABORATORY MANUAL

Prior to the development of this Student Laboratory Manual, MASTER project staff visited over 150 companies, conducted interviews with over 500 expert workers, and analyzed data from a national survey involving over 2800 participating companies. These investigations led to the development of a series of Instructor Handbooks, with each being fully industry-driven and specific to one of the technologies shown below:

Advanced CNC and CAM
Automated Equipment Repair
Computer Aided Design & Drafting
Conventional Machining
Industrial Maintenance
Instrumentation
LASER Machining
Manufacturing Technology
Mold Making
Tool And Die
Welding

Each Instructor's Handbook contains a collection of Technical Training Modules which are built around a Competency Profile for the specific occupation. **The Competency Profile which is the basis for this Student Laboratory Manual may be found on the following page (and on each of the tab pages in this book).**

This Student Laboratory Manual has been developed as an learning aid for both the instructor and for the student, and is intended to be used in conjunction with the Instructor's Handbook.

This Student Laboratory Manual is arranged by Duty groupings (Duty A, Duty B, etc.) with learning modules available for each Task Box on the Competency Profile.

This Student Laboratory Manual is supplied with an accompanying Instructor's Handbook for use by the instructor.

Each module in the Instructor's Handbook has a corresponding learning module in the Student Laboratory Manual.

CNC MACHINIST .... **programs, edits, sets up, and operates CNC lathes, mills and grinders to perform machining operations necessary to produce workpieces to referenced engineering standards.**

	Duties	Tasks												
A	Practice Safety	A-1 Follow safety manuals and all safety regulations/ requirements	A-2 Use protective equipment	A-3 Follow safe operating procedures for hand and machine tools	A-4 Maintain a clean and safe work environment	A-5 MSDS/ control chemical hazards								
B	Apply Mathematical Concepts	B-1 Perform basic arithmetic functions	B-2 Convert fractions/ decimals	B-3 Convert Metric/ English measurements	B-4 Perform basic algebraic operations	B-5 Use practical geometry	B-6 Understand basic trigonometry	B-7 Calculate speeds and feeds for machining	B-8 Use coordinate systems					
C	Interpret Engineering Drawings and Control Documents	C-1 Identify basic layout of drawings	C-2 Identify basic types of drawings	C-3 Review blueprint notes and dimensions	C-4 List the purpose of each type of drawing	C-5 Verify drawing elements	C-6 Practice Geometric Dimensioning and Tolerancing (GD&T)	C-7 Analyze bill of materials (BOM)	C-8 Describe the relationship of engineering drawings to planning	C-9 Understand and use quality systems	C-10 Verify standard requirements			
D	Recognize Different Manufacturing Materials and Processes	D-1 Identify materials with desired properties	D-2 Identify materials and processes to produce a part	D-3 Describe the heat treating process	D-4 Test metal samples for hardness	D-5 Understand welding operations								
E	Measure/ Inspect	E-1 Understand metrology terms	E-2 Select measurement tools	E-3 Measure with hand held instruments	E-4 Eliminate measurement variables	E-5 Measure/ inspect using surface plate and accessories	E-6 Inspect using stationary equipment							
F	Perform Conventional Machining	F-1 Prepare and plan for machining operations	F-2 Use hand tools	F-3 Operate power saws	F-4 Operate drill presses	F-5 Operate vertical milling machines	F-6 Operate horizontal milling machines	F-7 Operate metal cutting lathes	F-8 Operate grinding/ abrasive machines					
G	Perform Advanced Machining	G-1 Understand CNC basics	G-2 Program CNC machines	G-3 Operate CNC machining centers (mills)	G-4 Operate CNC turning centers (lathes)									
H	Use Verification and Communication Systems	H-1 Use personal computer	H-2 Use various operating systems	H-3 Use computer communications systems	H-4 Use verification systems	H-5 Use the Internet								
I	Program Using CAM System	I-1 Understand CAD/ CAM programs	I-2 Manipulate CAD functions	I-3 Process simple tool-path data	I-4 Create advanced surface models	I-5 Process complex tool-path functions								

CNC MACHINIST .... **programs, edits, sets up, and operates CNC lathes, mills and grinders to perform machining operations necessary to produce workpieces to referenced engineering standards.**

	Duties	Tasks												
A	Practice Safety	A-1 Follow safety manuals and all safety regulations/ requirements	A-2 Use protective equipment	A-3 Follow safe operating procedures for hand and machine tools	A-4 Maintain a clean and safe work environment	A-5 MSDS/ control chemical hazards								
B	Apply Mathematical Concepts	B-1 Perform basic arithmetic functions	B-2 Convert fractions/ decimals	B-3 Convert Metric/ English measurements	B-4 Perform basic algebraic operations	B-5 Use practical geometry	B-6 Understand basic trigonometry	B-7 Calculate speeds and feeds for machining	B-8 Use coordinate systems					
C	Interpret Engineering Drawings and Control Documents	C-1 Identify basic layout of drawings	C-2 Identify basic types of drawings	C-3 Review blueprint notes and dimensions	C-4 List the purpose of each type of drawing	C-5 Verify drawing elements	C-6 Practice Geometric Dimensioning and Tolerancing (GD&T)	C-7 Analyze bill of materials (BOM)	C-8 Describe the relationship of engineering drawings to planning	C-9 Understand and use quality systems	C-10 Verify standard requirements			
D	Recognize Different Manufacturing Materials and Processes	D-1 Identify materials with desired properties	D-2 Identify materials and processes to produce a part	D-3 Describe the heat treating process	D-4 Test metal samples for hardness	D-5 Understand welding operations								
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I	Program Using CAM System	I-1 Understand CAD/ CAM programs	I-2 Manipulate CAD functions	I-3 Process simple tool-path data	I-4 Create advanced surface models	I-5 Process complex tool-path functions								

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CNC-A1-HO
Follow Safety Manuals and All Safety Regulations/Requirements
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Assume responsibility for the personal safety of oneself and others;
b. Develop a personal attitude towards safety;
c. Interpret safety manual directives;
d. Identify and control common machine shop hazards; and,
e. Comply with established company safety practices.

Module Outline:

- I. Assume Responsibility for the Personal Safety of Oneself and Others
    - A. Safety is a way of life not an option
    - B. Always operate with alertness and safety foremost in mind
- II. Develop a Personal Attitude Towards Safety
    - A. The key to safety is individual safety
    - B. Everyone must develop a safe attitude
    - C. Each step of the operation must be carefully planned
- III. Interpret Safety Manual Directives
    - A. Read and understand safety manual
    - B. Read machine operation instructions
- IV. Comply with Established Safety Practices
    - A. Personal safety
        - 1. Body: keep body out of line of tool edge
        - 2. Proper lifting technique
            - a. Personal lifting
                - 1) Lift with the legs, not the back
                - 2) Proper physical position while lifting
                - 3) Proper clearance for carrying
                - 4) "Buddy system" for heavy lifting
            - b. Equipment lifting
                - 1) Checking ratings for lifting devices
                - 2) Checking lifting points on lifted item
                - 3) Overhead clearance requirements
                - 4) Static lifting devices (slings, jack stands) should be used instead of moving lifting devices (jacks or forklifts) for actually holding heavy items up while working on them
    - B. Eyes: always wear safety glasses
    - C. Head: keep long hair up; wear hard hat whenever required

- D. Ears: wear protection to prevent damage from noise
- E. Jewelry: no rings, watches, bracelets, necklaces (they can get caught in machinery and they are conductors of electricity)
- F. Clothing: keep sleeves and pant legs rolled down; and ties, strings, and belts away from moving parts
- G. No horse-play
- H. Do not talk to someone while that person is operating a machine
- I. Do not talk to someone while you are operating a machine

V. Identify and Control Common Machine Shop Hazards

- A. Chip formation
- B. Moving machine parts
- C. Spills and other debris
- D. Electrical lines
- E. Hydraulic and pneumatic lines

VI. Cover specific safety policies of the company

CNC-A1-LE

Follow Safety Manuals and All Safety Regulations/Requirements

Attachment 2: **MASTER** Laboratory Exercise

The purpose of this exercise is to learn to recognize hazards in the workplace. Many of the hazards which you will find there are common practices by people who simply no longer see the danger.

The instructor will guide all students through part of the facility. Each student should write down, in the space provided below, as many safety hazards as are found.

Remember, anyone can cause a hazard merely by failing to see the mop bucket that sits in front of the fire exit every day. Such tunnel vision is the result of familiarity and demonstrates the importance of keeping a fresh perspective *everyday*.

Due to the nature of this laboratory exercise, no answer key is possible.

Safety Hazards

Type	Location	Description

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

CNC-A2-HO
Use Protective Equipment
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:
- a. Wear protective safety clothing as required;
- b. Maintain and use protective guards and equipment on machinery;
- c. Locate and properly use protective equipment; and,
- d. Use lifting aids when necessary.

Module Outline:

- I. Wear Protective Safety Clothing as Required
  - A. Different types of safety clothing
    - 1. Protective from debris, cuts, and blows
      - a. Hard hat, safety glasses or goggles, work gloves when necessary
      - b. Sturdy footwear
      - c. Long sleeved shirt (sleeves rolled down and buttoned)
    - 2. Fire-retardant and fire-resistant clothing
      - a. Long sleeved, 100% cotton shirt
      - b. Long pants, 100% cotton
      - c. Leather chest protector, sleeves
    - 3. Optical filters to protect vision from intense light
      - a. Welding hood or goggles
      - b. Safety glasses or goggles for grinding
      - c. Tinted goggles for cutting torch work
    - 4. Breathing protection
      - a. Mask for dust, lint, smoke
  - B. Function and use of safety clothing
    - 1. Man made fiber clothing melts to worker's skin when ignited
    - 2. Prevents cuts and abrasions
    - 3. Keep shirt sleeves rolled down (hangs on equipment)
    - 4. Do not cuff pant legs (causes tripping)
    - 5. Do not wear jewelry
      - a. Catches in moving parts
      - b. Conducts electricity
    - 6. Do not wear neckties around moving parts of machinery
    - 7. Keep belts and apron strings tied and away from moving equipment
- II. Maintain and Use Protective Guards and Equipment on Machinery
  - A. Purposes of various guards

        1. Do not operate a machine until guards are in place
        2. Stop the machine to make adjustments or repairs
        3. Disconnect power before removing guards or panels
    B. Evaluation and maintenance of protective equipment
        1. Use only those electrical devices which have been approved by UL (Underwriters' Laboratories)
        2. Do not use defective equipment
        3. Report defective or unsafe equipment immediately
        4. Make sure equipment is properly grounded

III. Locate and Properly Use Protective Equipment
    A. Install safety barriers
    B. Use caution signs
    C. Install lock and tag devices
    D. Know where fire extinguishers are and how to use them

IV. Use Lifting Aids When Necessary
    A. Discuss recommended limits on single-person lifting
    B. Discuss proper lifting methods (use of the legs)
        1. Use your legs (bend your knees)
        2. Keep the load close to your body
        3. Don't twist your body while lifting
        4. Make sure you can see where you are going
        5. Wear support belts
    C. Discuss team-lifting
        1. Keep load the same height while lifting
        2. Move and lift on command
        3. Use dolly, wheelbarrow, or forklift
    D. Determine lifting ratings of lifting equipment
        1. Know how your forklift operates
        2. Understand load characteristics (weight, size, shape)
    E. Determine holding ratings of static lifting devices
    F. Evaluate positions on the workpiece for placement of lifting and holding devices

CNC-A2-LE
Use Protective Equipment
Attachment 2: MASTER Laboratory Exercise

The instructor will display as much protective equipment, such as welding masks, breathers, and hard hats as is practical and desirable. The instructor should demonstrate the proper use of this equipment.

Due to the nature of this exercise, no answer key is possible.

CNC-A2-LA
Use Protective Equipment
Attachment 3: **MASTER** Laboratory Aid

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

CNC-A3-HO
Follow Safe Operating Procedures for Hand and Machine Tools
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

- a. Identify and understand safe machine operating procedures; and,
- b. Demonstrate safe machine operation.

Module Outline:

- I. Identify and Understand Safe Machine Operating Procedures
  - A. Never make adjustments on a machine while it is running
    - 1. Keep guards in place at all times
    - 2. Discontinue power before servicing
    - 3. Keep body parts clear of moving machinery
    - 4. Beware of sharp edges and flying debris
    - 5. Secure work pieces to prevent slipping
    - 6. Never stand directly in line with blades or knives
    - 7. Avoid kickback
    - 8. Feed stack into machine correctly
  - B. Electrical safety
    - 1. Use only those electrical devices which have been approved by UL (Underwriters' Laboratories)
    - 2. Stand on dry surface when working on electrical equipment
    - 3. Replace defective cords or plugs on equipment
    - 4. Use only those tools that are in good condition
    - 5. Use only carbon dioxide or dry chemical fire extinguishers for control of electrical fires
    - 6. Obtain help when working on equipment that may become energized
  - C. Avoid horseplay and practical jokes
  - D. Keep work area clean.
- II. Demonstrate Safe Machine Operation
  - A. Good housekeeping
    - 1. Materials and equipment should be stacked straight and neat
    - 2. Keep aisles and walkways clear of tools, materials, and debris
    - 3. Dispose of scraps and rubbish daily
    - 4. Clean up spills
    - 5. Clean and store hand tools
  - B. Good techniques
    - 1. Always walk - do not run
    - 2. Never talk to or interrupt anyone who is operating a machine

3. Never leave tools or pieces of stock lying on table surface of a machine being used
4. When finished with a machine, turn power OFF and wait until blades or cutters have come to a complete stop before leaving
5. Check stock for defects before machining
    a. Do not use a machine until you understand it thoroughly
    b. Do not jam or rush stock into machinery
    c. Keep guards in place
    d. Make sure power is OFF before working on or servicing
6. Keep hands and fingers away from moving parts
7. Don't try to run too small a piece through the machine
8. Use a brush to clean the surface table
9. Keep your eyes focused on what you are working on
10. Never use an air hose to blow debris off yourself or other workers
11. Report faulty machinery to your supervisor
12. Make sure machinery is properly grounded
13. Never leave a piece of machinery that is running unattended
14. Make sure stack is solidly supported

C. Miscellaneous materials
1. Molten metal - can splash and cause serious burns
2. Chemicals - burn or irritate the skin or cause eye damage
3. Broken glass - causes cuts, can get in the eyes
4. Pointed objects - knives, screwdrivers, punches, staples can puncture the skin
5. Rough material - can scrape your skin and cause infections

D. Machinery
1. Understand the safety regulations that involve the guarding of moving parts
2. Know what parts of the equipment are energized
3. Use all safeguards that have been provided to protect people from machinery
4. See that all guards and protectors are in place before you start to work
5. If you must work nearer, turn the machine off and lock out the power
6. Never work in, around, or near dangerous, unguarded openings without wearing a safety belt and a lifeline that is properly seamed

E. One-fifth of all injuries on the job involve moving parts, machinery, or tools

CNC-A3-LE
Follow Safe Operating Procedures for Hand and Machine Tools
Attachment 2: MASTER Laboratory Exercise

For this exercise, the instructor should allow the students to observe other workers at their stations. The students should look for only practices related to safety. Upon returning to class, the students and instructor should discuss what they saw.

NOTE TO ALL STUDENTS: Unless your instructor tells you otherwise, all questions are to be directed to the instructor only. Do **not** disturb you fellow workers at their stations. Such distractions, in and of themselves, pose risks!

Due to the nature of this exercise, no answer key is possible.

CNC-A3-LA

Follow Safe Operating Procedures for Hand and Machine Tools

Attachment 3: MASTER Laboratory Aid

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

CNC-A4-HO
Maintain a Clean and Safe Work Environment
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:

- a. Keep work areas clean;
- b. Clean machine/hand tools when work is completed;
- c. Put tools away when work is finished;
- d. Keep isles clear of equipment and materials;
- e. Perform preventive maintenance as required; and,
- f. Understand chemical hazards and the use of Material Safety Data Sheets (MSDS).

Module Outline:

- I. Keep Work Areas Clean
  - A. Discuss the associated dangers of the most common hazards of the work place
    - 1. Tripping/falling hazards caused by spills, loose objects, etc.
      - a. Wipe up spills immediately
      - b. Dispose of scrap material
      - c. Do not wear loose clothing
      - d. Never roll sleeves or pants
      - e. keep shoe strings tied
      - f. Position electrical cords and air hoses in safe areas
    - 2. Chemical hazards
      - a. Inhalants
      - b. Chemical burns
      - c. Flammable liquids
      - d. Explosives and explosive combinations
      - e. Toxins
    - 3. Electrical hazards
    - 4. High-pressure hazards
  - B. Discuss methods of avoiding and correcting common hazards
- II. Clean Machine/Hand Tools When Work Is Completed
- III. Put Tools Away When Work Is Finished
- IV. Keep Isles Clear of Equipment and Materials
- V. Perform Preventive Maintenance as Required
  - A. Discuss that certain machines require extra precautions
  - B. Discuss how general maintenance enhances general safety
- VI. Understand the Use of Material Safety Data Sheets (MSDS)
  - A. What chemicals have MSDS?

B. Where are the MSDS kept?
C. What information is on the MSDS?
   1. Product identification
      a. Specific product name and common name
      b. Precautionary labeling
      c. Safety equipment
      d. Precautionary label statements
      e. Storage color code
   2. Hazardous components
   3. Physical data
      a. Boiling point
      b. Vapor pressure
      c. Melting point
      d. Vapor density
      e. Specific gravity
      f. Evaporation rate
      g. Solubility in water
      h. Percentage of volatile components by volume
      I. Appearance & odor
   4. Fire and explosion hazard data
      a. Flash point
      b. NFPA 704M rating
      c. Flammable limits (upper and lower)
      d. Fire extinguishing media
      e. Special fire-fighting procedures
      f. Toxic gases produced
   5. Health hazard data
      a. Threshold limit value
      b. Permissible exposure limit
      c. Toxicity
      d. Carcinogenicity
      e. Effects of over-exposure
      f. Target organs (those most affected by exposure)
      g. Medical conditions aggravated by exposure
      h. Routes of entry
      I. Emergency and first-aid procedures
   6. Reactivity data
      a. Stability
      b. Hazardous polymerization
      c. Conditions to avoid
      d. Incompatible materials
      e. Decomposition products
   7. Spill and disposal procedures
      a. Procedures: spill or discharge
      b. Procedures: disposal

   c. EPA hazardous waste number
8. Protective equipment
   a. Ventilation
   b. Respiratory protection
   c. Eye/skin protection
9. Storage and handling precautions
   a. Storage color code
   b. Special precautions
10. Transportation data and additional information
    a. Domestic transport
       1) DOT shipping name
       2) Hazard class
       3) UN/NA
       4) Labels
       5) Reportable quantity
    b. International
       1) IMO shipping name
       2) Hazard class
       3) UN/NA
       4) Labels

CNC-A4-LE
Maintain a Clean and Safe Work Environment
Attachment 2: MASTER Laboratory Exercise

The instructor will guide all students through part of the facility. Each student should write down as many safety hazards as are found. While this may appear to be an exact duplicate of CNC-A1, the purpose of this exercise is to determine how much more aware of safety and hazards the students have become.

Upon returning to class, the students and the instructor should discuss what the students observed on this tour. Each student should compare his answers to those from CNC-A1, noting any differences and the reasons for those differences.

Due to the nature of this laboratory exercise, no answer key is possible.

Safety Hazards

Type	Location	Description	Recommendations

CNC-A4-LA
Maintain a Clean and Safe Work Environment
Attachment 3: **MASTER** Laboratory Aid

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

CNC-A5-HO
MSDS/Control Chemical Hazards
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:

- a. Define hazardous material;
- b. Identify hazardous material;
- c. Know the physical and chemical characteristics;
- d. Describe storage, transportation, disposal of hazardous waste; and,
- e. Explain material safety data sheets.

Module Outline:

- I. Define Hazardous Materials According to the EPA
  - A. What makes a material hazardous?
    - 1. It is hazardous if it causes harm to people or environment
- II. Identify Hazardous Materials
  - A. Material Safety Data Sheets (MSDS)
    - 1. Companies that make and distribute hazardous substances must provide your company with a MSDS on hazardous material
    - 2. MSDS developed by OSHA
    - 3. MSDS is part of the Hazard Communication Standard or Right to Know regulation
    - 4. MSDS is an easy reference for information on hazardous substances
  - B. Information in MSDS
    - 1. What it is
    - 2. Who makes or sells it
    - 3. Where they are located
    - 4. Why it is hazardous
    - 5. How you can be exposed to the hazard
    - 6. Conditions that could increase the hazard
    - 7. How to handle the substance safely
    - 8. Protection to use while working with it
    - 9. What to do if exposed
    - 10. What to do if there is a spill or emergency
- III. Know the Chemical and Physical Characteristics
  - A. Corrosive
    - 1. Burns skin or eyes on contact
  - B. Explosive
  - C. Flammable

   1. Catches fire easily

D. Radioactive

E. Reactive
   1. Burns, explodes
   2. Releases toxic vapors

F. Toxic
   1. Causes illness or possibly death

IV. Describe Storage, Transportation, Disposal

A. Resource Conservation and Recovery Act (RCRA)
   1. Designed to reduce hazards of waste by tracking and regulating the substance
   2. Method used is called from cradle (creation) to grave (disposal)
   3. Tells what hazards are and how to keep track of them
   4. Sets up rules for handling wastes
   5. Provides strict documentation system to track them

B. Your employer may have to report to the Environmental Protection Agency (EPA) on how the company is meeting the RCRA responsibilities

C. The law requires companies that treat, store, or dispose of hazardous wastes to:
   1. Must have a permit
   2. Identify and analyze new hazardous waste
   3. Provide a secure facility that keeps unauthorized people out
   4. Inspect the facility regularly
   5. Have a contingency plan for fire, explosion, and spills
   6. Practice emergency response for fire, explosion, spills
   7. Provide proper protective clothing and equipment
   8. Maintain EPA-required records

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

CNC MACHINIST .... programs, edits, sets up, and operates CNC lathes, mills and grinders to perform machining operations necessary to produce workpieces to referenced engineering standards.

Duties		← Tasks →												
A	**Practice Safety**	A-1 Follow safety manuals and all safety regulations/ requirements	A-2 Use protective equipment	A-3 Follow safe operating procedures for hand and machine tools	A-4 Maintain a clean and safe work environment	A-5 MSDS/ control chemical hazards								
B	**Apply Mathematical Concepts**	B-1 Perform basic arithmetic functions	B-2 Convert fractions/ decimals	B-3 Convert Metric/ English measurements	B-4 Perform basic algebraic operations	B-5 Use practical geometry	B-6 Understand basic trigonometry	B-7 Calculate speeds and feeds for machining	B-8 Use coordinate systems					
C	**Interpret Engineering Drawings and Control Documents**	C-1 Identify basic layout of drawings	C-2 Identify basic types of drawings	C-3 Review blueprint notes and dimensions	C-4 List the purpose of each type of drawing	C-5 Verify drawing elements	C-6 Practice Geometric Dimensioning and Tolerancing (GD&T)	C-7 Analyze bill of materials (BOM)	C-8 Describe the relationship of engineering drawings to planning	C-9 Understand and use quality systems	C-10 Verify standard requirements			
D	**Recognize Different Manufacturing Materials and Processes**	D-1 Identify materials with desired properties	D-2 Identify materials and processes to produce a part	D-3 Describe the heat treating process	D-4 Test metal samples for hardness	D-5 Understand welding operations								
E	**Measure/ Inspect**	E-1 Understand metrology terms	E-2 Select measurement tools	E-3 Measure with hand held instruments	E-4 Eliminate measurement variables	E-5 Measure/ inspect using surface plate and accessories	E-6 Inspect using stationary equipment							
F	**Perform Conventional Machining**	F-1 Prepare and plan for machining operations	F-2 Use hand tools	F-3 Operate power saws	F-4 Operate drill presses	F-5 Operate vertical milling machines	F-6 Operate horizontal milling machines	F-7 Operate metal cutting lathes	F-8 Operate grinding/ abrasive machines					
G	**Perform Advanced Machining**	G-1 Understand CNC basics	G-2 Program CNC machines	G-3 Operate CNC machining centers (mills)	G-4 Operate CNC turning centers (lathes)									
H	**Use Verification and Communication Systems**	H-1 Use personal computer	H-2 Use various operating systems	H-3 Use computer communications systems	H-4 Use verification systems	H-5 Use the Internet								
I	**Program Using CAM System**	I-1 Understand CAD/ CAM programs	I-2 Manipulate CAD functions	I-3 Process simple tool-path data	I-4 Create advanced surface models	I-5 Process complex tool-path functions								

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Duty B

CNC-B1-HO
Perform Basic Arithmetic Functions
Attachment 1: MASTER Handout

Objective(s):

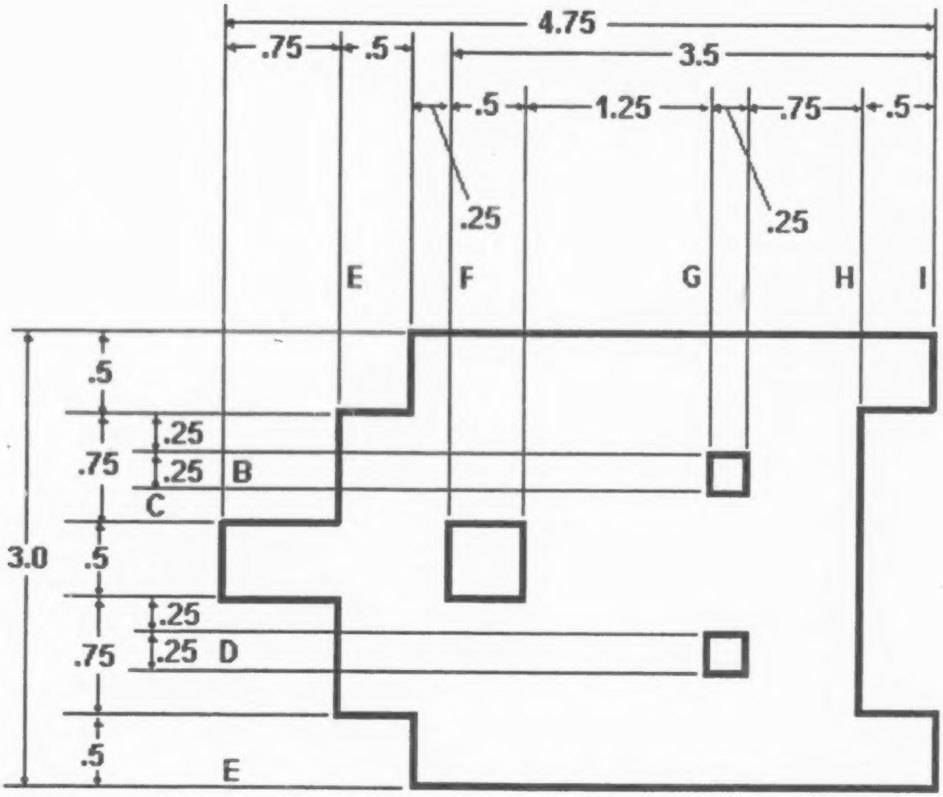
Upon completion of this unit the student will be able to:

- a. Add, subtract, multiply, and divide whole numbers;
- b. Add, subtract, multiply, and divide fractions; and,
- c. Add, subtract, multiply, and divide decimals.

Module Outline:

- I. Add, Subtract, Multiply, and Divide Whole Numbers
  - A. Addition of whole numbers
  - B. Subtraction of whole numbers
  - C. Multiplication of whole numbers
  - D. Division of whole numbers
  - E. Hierarchy of operations
- II. Add, Subtract, Multiply, and Divide Fractions
  - A. Common operations
    - 1. Least common denominator
    - 2. Factoring for reduction
    - 3. Improper fractions
    - 4. Mixed numbers
  - B. Addition
  - C. Subtraction
  - D. Multiplication
  - E. Division
- III. Add, Subtract, Multiply, and Divide Decimals
  - A. Aligning the decimal (addition and subtraction)
  - B. Moving the decimal
    - 1. In division, move the decimal to the right until it is eliminated in the divisor. Move the decimal the same number of places to the right in the dividend.
    - 2. In multiplication, count the total number of decimals places in the two numbers being multiplied. Beginning in the product at the *right-most digit,* count off the same number of places and place the decimal.

CNC-B1-LA
Perform Basic Arithmetic Functions
Attachment 2: **MASTER** Laboratory Aid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D
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E

CNC-B2-HO
Convert Fractions/Decimals
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Write fractions as decimals;
b. Write decimals as fractions; and,
c. Use fractions and decimals interchangeably.

Module Outline:

I. Write Fractions as Decimals
   A. Understand and be able to use equivalent fractions
   B. Write fractions in lowest terms
   C. Understand improper fractions and mixed numbers
   D. Be able to write fractions as decimals by performing the indicated division
II. Write Decimals as Fractions
   A. Understand the place value in decimals
   B. Understand how to find the fraction or mixed number equivalent of decimals by writing the digits over the place value and reducing this to the lowest terms
III. Use Fractions and Decimals Interchangeably
   A. Understand how fractions and decimals can be used interchangeably to represent the same value
   B. Be able to determine the best representation, fraction or decimal, for a given industrial problem
IV. Common Technical Conversions
   A. These are the six most important conversions from denominative fractions to decimal fractions
      1. 1/64 is *about* .016 (sixteen thousandths)
      2. 1/32 is *about* .031 (thirty-one thousandths)
      3. 1/16 is *about* .062 (sixty-two thousandths)
      4. 1/8 is .125 (one hundred twenty-five thousandths)
      5. 1/4 is .250 (two hundred fifty thousandths)
      6. 1/2 is .500 (five hundred thousandths)
   B. The trick to quickly converting these fractions is to think of them just like they were building blocks. For example, how much is 11/16 inch in thousandths? 11/16 is actually 1/2 + 1/8 + 1/16, so it is also .500 + .125 + .062, or .687.
   C. If you, the technician, will learn the six basic conversions listed above, then you will have won half the battle of fractional conversions.

D. It is also helpful to think in thousandths. Don't think of .5 as one-half or five tenths, think of it as 500 thousandths. Thinking this way will automatically align the decimal places for you and allow you to quickly add and subtract measurements.

E. By the same token, it is easier to think in 64ths than it is to carry around all those fractions in your head. Converting fractions can cause errors because it is another step. Since the assumed standard of tolerance in binary fractions is 1/64 inch, *think that way*. One-half becomes 32/64; one-eighth, 8/64. The arithmetic almost does itself when all the fractions in your head have common denominators.

CNC-B3-HO
Convert Metric/English (Customary or English) Measurements
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Make inch, foot, and yard (English) measurements using rulers, calipers, and height gages;
b. Make millimeter, centimeter, meter (metric) measurements using metric rulers, calipers, and height gages; and,
c. Use English and metric measurements interchangeably.

Module Outline:

I. Make Inch, Foot, and Yard (English) Measurements Using Rulers, Calipers, and Height Gages
    A. Know the units of length, their symbols and relationships
    B. Be able to convert from one unit of length to another
    C. Be able to choose the degree of accuracy desired when making length measurements
    D. Be able to measure to the nearest 1/64 inch using rulers, and to the nearest .001" using calipers and height gages
II. Write Millimeter, Centimeter, and Meter (Metric) Measurements Using Metric Rulers, Calipers, and Height Gages
    A. Know the metric units of length, their symbols and relationships
    B. Be able to convert from one metric unit of length to another
    C. Be able to choose the degree of accuracy desired when making metric unit of length measurements
    D. Be able to measure to the nearest centimeter or millimeter using metric rulers, calipers, and height gages
III. Convert Metric/English Units of Length
    A. Know how to convert metric to English units using a conversion factors table
    B. Know how to convert English units to metric units using a conversion factors table

CNC-B4-HO
Perform Basic Algebraic Operations
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:

- a. Understand basic algebraic symbols and expressions; and,
- b. Use equations to solve problems.

Module Outline:

- I. Understand Basic Algebraic Symbols and Expressions
    - A. Symbols
        - 1. Addition "+"
        - 2. Subtraction "-"
        - 3. Multiplication "·"; "x", and parentheses
        - 4. Division "÷" and "/"
        - 5. Exponents are generally limited to the term "square" in linear measurements. This is the "^{2}" notation.
    - B. Expressions
        - 1. Sum: the total amount resulting from addition
        - 2. Difference: the remaining amount resulting from subtraction
        - 3. Product: the total amount resulting from multiplication
        - 4. Exponent: a superscript which indicates the number of times a quantity is multiplied by itself
        - 5. Quotient: the amount resulting from division
- II. Use a Few Easy-to-Remember Rules to Solve Equations
    - A. *P*lease *E*xcuse *M*y *D*ear *A*unt *S*ue indicates the order in which equations are solved. Each letter shows one of the algebraic notations or functions: Parentheses, Exponents, Multiply, Divide, Add, Subtract.
        - 1. In the expression $(x - y)^2 + 2x^2 - y^2$, the *p*arentheses, which must be worked first, indicate that y must be subtracted from x. Since we don't know what x and y are, we can't do that, and must move on.
        - 2. The next step is to square the term $(x - y)$, as indicated by the *e*xponent. This gives us $x^2 - 2xy + y^2 + 2x^2 - y^2$.
        - 3. There is no operable *m*ultiplication or *d*ivision in this expression, so we move on.
        - 4. Grouping all the like terms to make seeing the answer easier, we have $x^2 + 2x^2 + y^2 - y^2 - 2xy$.
        - 5. *A*dding, we now have $3x^2 + y^2 - y^2 - 2xy$.
        - 6. *S*ubtracting, which is the final step, renders $3x^2 - 2xy$.

B. *FOIL* gives the order in which you multiply the terms in expressions. Let us go back to squaring (multiplying by itself) (x - y) from the expression above.

   1. *F*irst terms first, so, in (x - y)(x - y), multiply the two x's first. This give us x^2.
   2. *O*utside terms come next, so multiply the first x by the second y. This gives us $x^2 - xy$.
   3. *I*nside terms come next, so multiply the first y by the second x. This gives us $x^2 - xy - xy$.
   4. *L*ast terms are last, so multiply the two y's. This gives us a complete (if complex) $x^2 - xy - xy + y^2$.
   5. Simplifying gives us the expression $x^2 - 2xy + y^2$.

C. Thinking about algebra can be daunting to almost anybody, but once you see that algebra is just juggling done with numbers and with a lot of two-dollar words stuck all over it, algebra becomes rather simple. Remember, algebra is just taking the four basic mathematic operations (addition, subtraction, multiplication, and division) and using them to find out something that you didn't know to start with.

D. Word problems are what you will encounter every day in the shop. Someone will tell you to get so much material and make so many parts from it. As you progress in skill, they will tell you to get such-and-such material and make so many parts from it. Your mastery of basic algebra will make these problems easy to solve.

CNC-B5-HO
Use Practical Geometry
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this module the student will be able to:

a. Calculate angles;
b. Calculate length of triangle sides;
c. Calculate radius, diameter, circumference, and area of a circle; and,
d. Understand the applications of planar geometry to solid forms.

Module Outline:

I. Some Rules of Angles
  A. Angles are usually expressed in degrees, minutes, and seconds
  B. No angle has more than 360°
  C. Angles have three points which determine them
  D. An angle having 90° is a right angle
II. Triangles
  A. Pythagorean Theorem: $a^2 + b^2 = c^2$
  B. All the angles in a triangle will add up to 180°, every day, every time, every triangle
  C. Have three corners. If one of them is 90°, then it is a right triangle.
  D. The absolute size of a triangle cannot be determined by its angles alone. At least one side must be known.
III. Circle
  A. 360°, every day, every time, every circle
  B. Pi (π) 3.1416 and its importance
  C. $2\pi r = d$, where r is the circle's radius and d, its diameter
IV. Rectangles and Parallelograms
  A. Squares and rectangles
    1. Have four 90° corners
    2. Squares are rectangles all of whose sides are equal
  B. Parallelograms
    1. Have four corners not 90°
    2. Have (at least) two parallel sides
V. Relating Planar Geometry to Solid Forms

In reality, planar geometry is an abstract way of looking at *parts* of solid things. Look at a piece of 1" CRS—at each end, it is a circle, so all the rules of circles apply to it, but only when looked at from the end. When you look at it from the sides, the rules for lines apply. So, that piece of 1" CRS, which is actually a cylinder, can be looked at as two circles joined by a line. Square workpieces have the same properties. No matter which way you look at them, each face is a

rectangle or a parallelogram; and each face is subject to the rules of rectangles and parallelograms. Tapers are unequal circles joined by an incomplete triangle.

CNC-B6-HO
Understand Basic Trigonometry
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:

- a. Solve for unknown angles;
- b. Solve for unknown sides; and,
- c. Calculate bolt hole patterns.

Module Outline:

- I. Solve for Unknown Angles
  - A. Right triangles
    - 1. Sine Law: sin a = side opposite divided by hypotenuse
    - 2. Cosine Law: cos a = side adjacent divided by hypotenuse
    - 3. Tangent Law: tan a = side opposite divided by side adjacent
    - 4. *O*scar *H*as *A H*eap *O*f *A*pples is a quick device to remember the above three runes.
      - a. Sine $\angle$ = *O*pposite/*H*ypoteneuse
      - b. Cosine $\angle$ = *A*djacent/*H*ypoteuse
      - c. Tangent $\angle$ = *O*pposite/*A*djacent
  - B. Oblique Triangles
    - 1. Lengths of three sides (A, B, C) all known
      - a. Cos $a = (B^2 + C^2 - A^2)/2BC$
      - b. Sin $b = (B \times \sin a)/A$
      - c. $c = 180° - (a + b)$
    - 2. Two angles (a and b) known
      $c = 180° - (a + b)$
    - 3. Two sides and interior angle (A, c, B) known
      - a. Tan $a = (A \times \sin c)/B-(A \times \cos c)$
      - b. $b = 180° - (a + c)$
      - c. $C = (A \times \sin c)/\sin a$
    - 4. Two sides and an opposite angle (a, A, B) known
      - a. Sin $b = (B \times \sin a)/A$
      - b. $c = 180° - (a + b)$
      - c. $C = (A \times \sin c)/\sin a$
- II. Solve for Unknown Sides
  - A. Right triangles, any two sides known, where C is the hypotenuse
    $A^2 + B^2 = C^2$
  - B. One side and two angles (a, b, A) known
    - 1. $c = 180° - (a + b)$
    - 2. $B = (A \times \sin b)/\sin a$

        3. $C = (A \times \sin c)/\sin a$

    C. Two sides and the interior angle (A, B, *c*) known

       $C = \sqrt{[A^2 + B^2 - (2AB \times \cos c)]}$

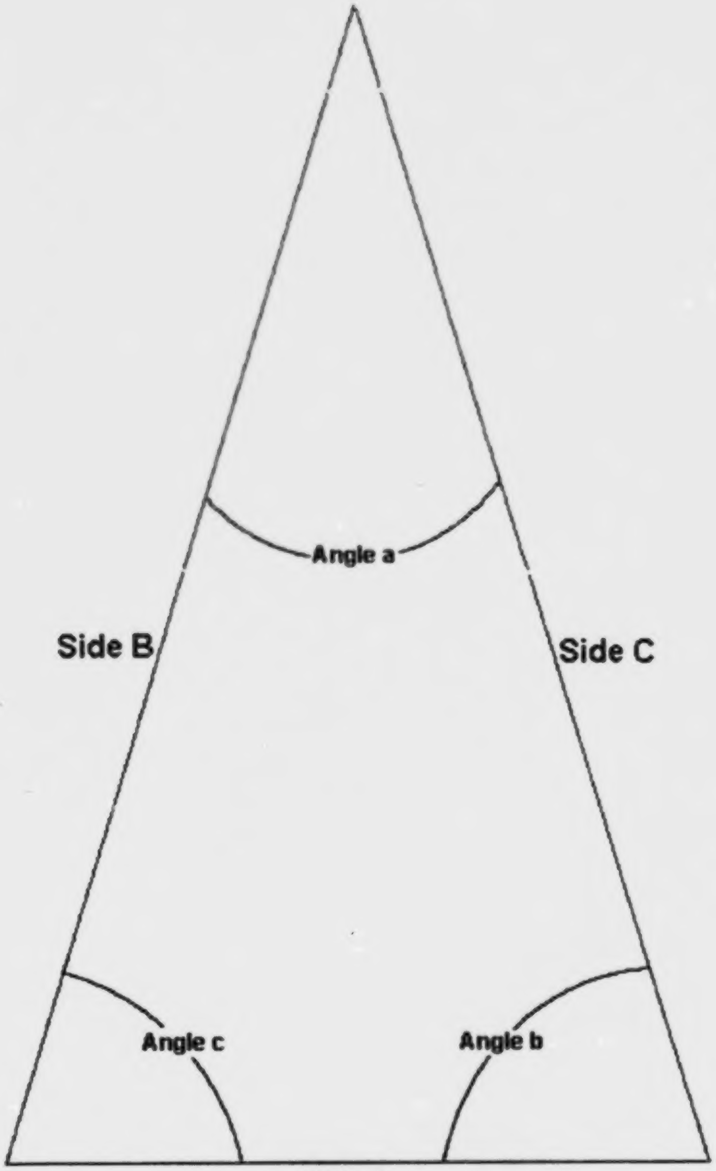
    D. Three angles known

       It is impossible to determine the actual length of any side when only the sizes of the three angles are known. The length of at least one side *must* be known in order to calculate the lengths of the other sides.

III. Calculate Bolt Hole Patterns

    A. Discuss the construction of reference triangles to solve bolt-hole patterns

    B. Discuss circles and their uses in figuring bolt-hole patterns.


Angle a
Side B
Side C
Angle c
Angle b

Side A
Basic Triangle - CNC-B6

CNC-B7-HO
Calculate Speeds and Feeds for Machining
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:

- a. Calculate RPM for various metals and various tools; and,
- b. Calculate feed for various metals, tools, and depths of cut.

Module Outline:

- I. Calculate RPM for Various Metals and Various Tools
  - A. Cutting speed (CS) defined - the surface feet per minute (sf/min) or meters per minute (m/min) at which the metal may be machined efficiently. When work is machined on a lathe, it must be turned at a specific number of revolutions per minute (rpm), *depending on its diameter*, to achieve the proper cutting speed. When work is machined on a milling machine, the cutter must be revolved at a specified number of rpm's, *depending on its diameter*, to achieve the proper cutting speed.
  - B. Factors affecting proper cutting speed
    - 1. Type of work material (aluminum, bronze, steel, etc.)
    - 2. Type of cutter (high-speed, carbide etc.)
    - 3. Diameter of the cutter
    - 4. Surface finish required
    - 5. Depth of cut
    - 6. Rigidity of the machine and the work setup
  - C. Sources for determining recommended cutting speeds
    - 1. *Machinery's Handbook*
    - 2. The text
    - 3. Cutting tool and insert manufacturers
    - 4. Experience of the machinist
  - D. Determining correct RPM
    - 1. Inch RPM calculations ...
      - RPM = (CS x 4) ÷ Diam.
    - 2. Metric RPM calculations ...
      - RPM = (CS (m) x 1000) ÷ (π x Diam. (mm))
    - 3. See charts 7.1 and 7.2 in this module
  - E. Problems related to using the wrong cutting speed
    - 1. Cutting speed too slow
      - a. Time will be lost for machining (low production rates)
      - b. Broken tool bits
    - 2. Cutting speed too fast

    a. Cutting tool edge breaks down
    b. Loss in production time due to reconditioning/replacing the tool
  F. Student practice using the "Determining Correct RPM" exercise and recommended speed charts found in this module
II. Calculate Feed for Various Metals, Tools, and Depths of Cut
  A. Feed defined - feed may be defined as the distance the tool advances into the work for every revolution.
    1. When work is machined on a lathe, feed is the distance, in inches (or millimeters), the cutting tool advances along the length of the work for every revolution of the spindle. Lathe feeds are generally expressed as inches (or millimeters) per revolution (ipr).
    2. When work is machined on a milling machine, feed is the distance, in inches (or millimeters) per minute, that the work moves into the cutter. Milling feeds are generally expressed as inches (or millimeters) per minute (ipm).
  B. Factors affecting proper feed
    1. Depth and width of cut
    2. Design or type of cutter
    3. Sharpness of the cutter
    4. Workpiece material
    5. Strength and uniformity of the workpiece
    6. The of finish and accuracy required
    7. Power and rigidity of the machine
  C. Sources for determining cutting optimal cutting speeds
    1. *Machinery's Handbook*
    2. The text
    3. Cutting tool and insert manufacturers
    4. Experience of the machinist
  D. Methods for determining correct feed
    1. Depth of cut - rule of thumb
      a. When possible, only two cuts should be used to bring a part to size: a roughing cut and a finishing cut.
      b. Since the purpose of a roughing cut is to remove excess material quickly and surface finish is not too important, a heavy depth of cut with a course feed should be used.
      c. The finishing cut is used to bring the diameter to size and produce a good surface finish and therefore a lighter depth of cut with a fine feed should be used.
      d. If much material must be removed, the roughing cuts should be as deep as possible to reduce the size of the part to within .020" to .030" of the size required.
    2. Lathe feed guidelines

  1. Roughing - .010" to .030" (.25 mm to .75 mm) per revolution
  2. Finishing - .003" to .010" (.07 mm to .25 mm) per revolution
  3. See chart 7.4 in this module
3. Mill feed guidelines
  a. Inch feed calculation ...
    Feed (ipm) = N x chip per tooth x RPM
    where N = number of teeth on the cut
  b. Metric feed calculation ... feed (mm/min) = same as above
  c. See charts 7.4 and 7.5 in this module

E. Problems related to using the wrong feed
  1. Feed speed too slow
    a. Time will be lost for machining (low production rates)
    b. Broken tool bits
  2. Feed too fast
    a. Cutting tool edge breaks down
    b. Loss in production time due to reconditioning/replacing the tool

F. Student practice using the "Calculate Speeds and Feeds for Machining" exercise and the recommended feed charts found in this module

CNC-B7-LA
Calculate Speeds and Feeds for Machining
Attachment 2: MASTER Laboratory Aid

TABLE 7.1

Lathe Cutting Speeds in Feet & Meters Per Minute Using a High-Speed Toolbit						
Material	Turning & Boring				Threading	
	Rough Cut		Finish Cut			
	ft/min	m/min	ft/min	m/min	ft/min	m/min
Machine Steel	90	27	100	30	35	11
Tool Steel	70	21	90	27	30	9
Cast Iron	60	18	80	24	25	8
Bronze	90	27	100	30	25	8
Aluminum	200	61	300	93	60	18

TABLE 7.2

Milling Machine Cutting Speeds				
Material	High-Speed Steel Cutter		Carbide Cutter	
	ft/min	m/min	ft/min	m/min
Machine Steel	70-100	21-30	150-250	45-75
Tool Steel	60-70	18-20	125-200	40-60
Cast Iron	50-80	15-25	125-200	40-60
Bronze	65-120	20-35	200-400	60-120
Aluminum	500-1000	150-300	1000-2000	150-300

TABLE 7.3

Feeds for Various Materials (Using a High-Speed Cutting Tool)				
Materials	Rough Cuts		Finish Cuts	
	Inches	Millimeters	Inches	Millimeters
Machine Steel	0.010-0.020	0.25-0.50	0.003-0.010	0.07-0.25
Tool Steel	0.010-0.020	0.25-0.50	0.003-0.010	0.07-0.25
Cast Iron	0.015-0.025	0.40-0.65	0.005-0.012	0.13-0.30
Bronze	0.015-0.025	0.40-0.65	0.003-0.010	0.07-0.25
Aluminum	0.015-0.030	0.40-0.75	0.005-0.010	0.13-0.25

TABLE 7.4

Recommended Feed per Tooth (High-Speed Steel Cutters)										
Material	Face Mills		Helical Mills		Slotting & Side Mills		End Mills		Form-Relieved Cutters	
	In.	mm	In.	mm	In.	mm	In.	mm	In.	mm
Aluminum	0.022	0.55	0.018	0.45	0.013	0.33	0.011	0.28	0.007	0.18
Brass & Bronze (medium)	0.014	0.35	0.011	0.28	0.008	0.20	0.007	0.18	0.004	0.10
Cast Iron (medium)	0.013	0.33	0.010	0.25	0.007	0.18	0.007	0.18	0.004	0.10
Machine Steel	0.012	0.30	0.010	0.25	0.007	0.18	0.006	0.15	0.004	0.10
Tool Steel (medium)	0.010	0.25	0.008	0.20	0.006	0.15	0.005	0.13	0.003	0.08
Stainless Steel	0.006	0.15	0.005	0.13	0.004	0.10	0.003	0.08	0.002	0.05

TABLE 7.5

Recommended Feed per Tooth (Cemented-Carbide-Tipped Cutters)										
Material	Face Mills		Helical Mills		Slotting & Side Mills		End Mills		Form-Relieved Cutters	
	In.	mm	In.	mm	In.	mm	In.	mm	In.	mm
Aluminum	0.020	0.50	0.016	0.40	0.012	0.30	0.010	0.25	0.006	0.15
Brass & Bronze (medium)	0.012	0.30	0.010	0.25	0.007	0.18	0.006	0.15	0.004	0.10
Cast Iron (medium)	0.016	0.40	0.013	0.33	0.010	0.25	0.008	0.20	0.005	0.13
Machine Steel	0.016	0.40	0.013	0.33	0.009	0.23	0.008	0.20	0.005	0.13
Tool Steel (medium)	0.014	0.35	0.011	0.28	0.008	0.20	0.007	0.18	0.004	0.10
Stainless Steel	0.010	0.25	0.008	0.20	0.006	0.15	0.005	0.13	0.003	0.08

CNC-B8-HO
Use Coordinate Systems
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Identify points using the Cartesian coordinate system;
b. Identify points using the absolute dimensioning system;
c. Identify points using the incremental dimensioning system; and,
d. Identify points using the polar coordinate system.

Module Outline:

I. Identify Points Using the Cartesian Coordinate System
    A. Describe the Cartesian (rectangular) coordinate system - the basis for all machine movement
        1. Define *axis* - any direction of movement on a machine tool. The spindle is always defined as the Z axis on 3 axis systems.
        2. Discuss the plus and minus aspects of an axis
        3. Discuss the quadrants I, II, III, and IV. Note that the signs for the X- and Y-axes change for the different quadrants.
        4. Discuss the concept of three dimensional locations
        5. Discuss how points are described in both 2- and 3-axis systems
        6. Describe how a part fits into the axis system
II. Identify Points Using the Polar Coordinate System
    A. Describe the *polar coordinate system* - a system by which all points are located around a known location (or pole).
        1. Points are usually identified by a known distance from the pole and a given angle from the horizontal (3:00 o'clock position equals zero degrees)
        2. Positive angles are measured from angle zero in a counterclockwise direction
        3. Negative angles are measured from angle zero in a clockwise direction
    B. Student practice
III. Locate Points Using the Absolute Dimensioning System
    A. Define *absolute positioning*- in absolute positioning, all machine locations are taken from one fixed zero (origin) point. This origin point does not change.
    B. This corresponds to the datum dimensioning method used by drafters. In datum dimensioning, all dimensions on a drawing are placed in reference to one fixed zero point.
    C. Student practice

IV. Locate Points Using the Incremental Dimensioning System
  A. Define *incremental positioning*- in incremental positioning, the X0/Y0 moves with each position change. The current position, in fact, becomes the X0/Y0 for the next positioning move.
  B. This corresponds to the delta dimensioning method used by drafters. In delta dimensioning, all dimensions on a drawing are "chain-linked." Each location is dimensioned from the previous one.
  C. Student practice

CNC MACHINIST .... **programs, edits, sets up, and operates CNC lathes, mills and grinders to perform machining operations necessary to produce workpieces to referenced engineering standards.**

Duties		Tasks												
A	**Practice Safety**	A-1 Follow safety manuals and all safety regulations/ requirements	A-2 Use protective equipment	A-3 Follow safe operating procedures for hand and machine tools	A-4 Maintain a clean and safe work environment	A-5 MSDS/ control chemical hazards								
B	**Apply Mathematical Concepts**	B-1 Perform basic arithmetic functions	B-2 Convert fractions/ decimals	B-3 Convert Metric/ English measurements	B-4 Perform basic algebraic operations	B-5 Use practical geometry	B-6 Understand basic trigonometry	B-7 Calculate speeds and feeds for machining	B-8 Use coordinate systems					
C	**Interpret Engineering Drawings and Control Documents**	C-1 Identify basic layout of drawings	C-2 Identify basic types of drawings	C-3 Review blueprint notes and dimensions	C-4 List the purpose of each type of drawing	C-5 Verify drawing elements	C-6 Practice Geometric Dimensioning and Tolerancing (GD&T)	C-7 Analyze bill of materials (BOM)	C-8 Describe the relationship of engineering drawings to planning	C-9 Understand and use quality systems	C-10 Verify standard requirements			
D	**Recognize Different Manufacturing Materials and Processes**	D-1 Identify materials with desired properties	D-2 Identify materials and processes to produce a part	D-3 Describe the heat treating process	D-4 Test metal samples for hardness	D-5 Understand welding operations								
E	**Measure/ Inspect**	E-1 Understand metrology terms	E-2 Select measurement tools	E-3 Measure with hand held instruments	E-4 Eliminate measurement variables	E-5 Measure/ inspect using surface plate and accessories	E-6 Inspect using stationary equipment							
F	**Perform Conventional Machining**	F-1 Prepare and plan for machining operations	F-2 Use hand tools	F-3 Operate power saws	F-4 Operate drill presses	F-5 Operate vertical milling machines	F-6 Operate horizontal milling machines	F-7 Operate metal cutting lathes	F-8 Operate grinding/ abrasive machines					
G	**Perform Advanced Machining**	G-1 Understand CNC basics	G-2 Program CNC machines	G-3 Operate CNC machining centers (mills)	G-4 Operate CNC turning centers (lathes)									
H	**Use Verification and Communication Systems**	H-1 Use personal computer	H-2 Use various operating systems	H-3 Use computer communications systems	H-4 Use verification systems	H-5 Use the Internet								
I	**Program Using CAM System**	I-1 Understand CAD/ CAM programs	I-2 Manipulate CAD functions	I-3 Process simple tool-path data	I-4 Create advanced surface models	I-5 Process complex tool-path functions								

CNC PM4
01/8/99

CNC-C1-HO1
Identify Basic Layout of Drawings
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:
- a. Identify types of lines within a drawing;
- b. List the essential components found in the title block;
- c. Locate bill of materials in a drawing; and,
- d. List the components found in the revision block.

Module Outline:

- I. Identify Types of Lines Within a Drawing
  - A. Break
    - 1. **Short**: a generally freehand, heavy, wavy line; indicating that the part is continuous and unchanged between the lines
      - a. Square break
      - b. Solid, round break
      - c. Hollow, round break
    - 2. **Long**: a thin line broken by zig-zags indicating that the part is continuous and unchanged between the lines
  - B. Center Lines
    - 1. A thin, broken line composed of alternating long and short lines, evenly spaced
    - 2. Uses
      - a. To show the center of a circle, arc, or part
      - b. To show that a part is bilaterally symmetrical. Used in conjunction with three parallel lines at each end
      - c. To indicate motion in conjunction with phantom lines
  - C. Cutting Plane
    - 1. A heavy, broken line whose ends, which have arrowheads pointed in the direction of the drawing, are perpendicular to the body of the line. Sometimes shown as one long and two short alternating lines.
    - 2. To indicate an imaginary cut through a piece; this line may be offset
  - D. Dimension Lines
    - 1. Thin, solid lines having arrowheads at both ends. The center is left open for dimensional specifics.
    - 2. Show the size of the piece relative to the line's direction
  - E. Extension Lines

    1. Thin, solid lines visibly removed from the edge to which they refer
    2. Used in conjunction with dimensions lines to show the sizes of objects

F. Hidden (Invisible) Lines
    1. Thin, evenly broken line
    2. Used to delineate any feature not visible in the particular view

G. Leader
    1. Thin, solid line with one arrowhead (when ending on an edge) or a dot (when ending on a surface) at one end and a bend that changes the line's direction at the other
    2. To annotate the drawing

H. Object (Visible) Lines
    1. Very heavy, solid lines
    2. Demarcates edges, surfaces, and corners in the visible view

I. Phantom Lines
    1. Thin line composed of one long and two short, equally spaced parts
    2. Uses
        a. Indicate alternate positions
        b. Demonstrate mating surfaces
        c. Show repetitious details

J. Screw Threads
    1. Three methods
        a. Actual drawing (seldom used)
        b. Schematic representation
        c. Simplified representation
    2. To display threading on parts. When marked with a "B" indicates a bore or internal thread.

K. Section
    1. Thin, solid lines, usually at a definite angle to the horizontal
    2. To indicate that the view has been cut off from the main part or that the part has been cut in two
    3. Sometimes used to identify specific materials

J. Precedence of Lines: On occasion, lines in a drawing may be superimposed. When this occurs, the lines are shown in the following order; e.g., visible lines are shown instead of any others; etc.
    1. Visible (Object) line
    2. Hidden (Invisible) line
    3. Cutting plane line
    4. Center line
    5. When either a visible or a hidden line occludes a center line, the ends of the center line are detached from the *outside* edge of the part

II. List the Essential Components Found in the Title Block--note That Title Blocks Are Not Fully Standardized and That Their Contents May Vary from Company to Company

A. The title block is usually found in the lower right-hand corner.

B. Components

1. Name and address of the manufacturer or designer
2. *Title* or brief description of parts
3. *Part Number* identifying the specific part
4. *Drawing Number* identifying the specific *drawing*
5. *Drawn by/Date* shows the drafter and the date of the drawing's completion
6. *Checked by/Date* shows the drawing's inspector and the date of approval
7. *Replaces* lists a part number that the new part will supersede
8. *Replaced by* lists a part that supersedes the part in the drawing. If the drawing is the most current, there will be a slash through this block.
9. *Scale* shows the proportion of the drawing to life
    a. *Full* indicates that the drawing is life-sized
    b. *Half* indicates that the drawing is one-half life size *in each dimension*
10. *Page* shows both the current page, *p*, and the total number of pages, *t*, in this format: *p of t*
11. *Tolerances* show the size limits of dimensions that are not specifically dimensioned in the drawing. These general tolerances are always secondary to tolerances listed in the drawing
12. *Heat Treatment* shows the required heat treatment and hardness specifications. If there are no specifications, then the box says NONE.
13. *Material* shows the exact material from which the part must be made
14. *Finish* indicates the general surface finish of the completed part
15. *Code Identification Number* identifies the specific manufacturer or design group. The number is provided by the Federal Government.
16. *Size* shows the physical size of the draft paper
17. The word NOTED in any block means that the information is supplied in the body of the drawing at or near the relevant item

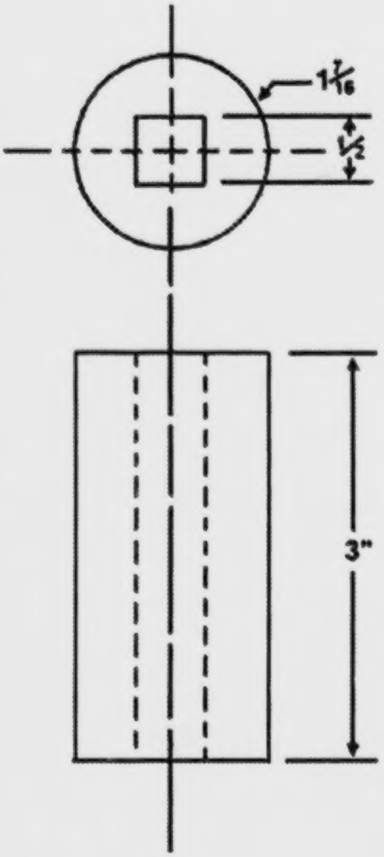
III. Locate Bill of Materials in a Drawing: The Materials List Is Usually Located Immediately above the Title Block.

IV. List the Components Found in the Revision Block

A. *Zone* refers to area which is to be changed. Large drawings generally have an alphanumeric coordinate system for clarity.

B. *Revision* specifies the exact change in the part. It is identified by a letter.
C. *Description* contains a brief description of the revision
D. *Date* is the effective date of the revision
E. *Apvd* abbreviates Approved. This is the identification of the inspector who approved the changes.

CNC-C1-HO2
Identify Basic Layout of Drawings
Attachment 2: MASTER Handout



SQUARE HOLE IN A ROUND PEG			
PART NO.	1010106	DRAWING NO.	A1576B
CHECKED BY	R. van Rijn 10/31/97		
REPLACES	A. Rand		
SCALE	1010071	REPLACED BY	———
TOLERANCES	± 1/64	PAGE	1 of 1
MATERIAL	Plutonium	FINISH	RMS

CNC-C2-HO
Identify Basic Types of Drawings
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Identify orthographic views;
b. Identify positions of views (top, front, side, and auxiliary);
c. Visualize one or more views from a given view;
d. Identify isometric views;
e. Identify exploded isometric drawings; and,
f. Identify assembly drawings.

Module Outline:

I. Identify Orthographic Views
    A. Characteristics of orthography: all views perpendicular to the viewer; no vanishing points
    B. Review the *projection planes*
II. Identify Positions of Views
    A. Top
    B. Front
    C. Side
    D. Auxiliary
III. Visualize One or More Views from a Given Angle
IV. Identify Isometric Views: All Angles at the Reference Origin Are 120°
V. Identify Exploded Isometric Drawings
VI. Identify Assembly Drawings

CNC-C3-HO
Review Blueprint Notes and Dimensions
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Explain basic blueprint terminology;
b. Identify the types of dimensions;
c. Identify general note symbols;
d. Locate notes on a print;
e. Interpret commonly used abbreviations and terminology;
f. Determine tolerances associated with dimensions on a drawing;
g. Determine the tolerance for a reference dimension;
h. Determine the surface finish for a given part; and,
i. List the essential components found in the general drawing notes.

Module Outline:

I. Explain Basic Blueprint Terminology
   A. Print Definitions
      1. **Print**: an exact copy of an engineering drawing
      2. **Engineering drawing:** the original design of anything as drawn by the drafter
   B. Print Parts and Terms
      1. **Title Block**: an area for the controlling information of a document, usually set apart in the lower right-hand corner
      2. **Print Body**: the actual drawing of the item, normally consisting of several views
      3. **View**: the angle of observation of the artist, usually the top, front, and right side of the item
      4. Projections
         a. **Orthographic**: all views are perpendicular to the drafter's field of vision, lacks vanishing points
         b. **Isometric**: built around a central point whose radiant axes are equally spaced at 120°
         c. Other **Axonometric** Views: briefly discuss other views, such as diametric
      5. Angles of Projection
         a. **First Angle Projections** are usually European and SI
         b. **Third Angle Projections** are North American and either SI or SAE

II. Identify the Types of Dimensions
   A. Physical Dimensions

1. **Linear** dimensions show height, width, and length as direction along a straight line
2. **Angular** dimensions display the sizes of angular features
    a. **Angle of the arc** is size of the actual angle, usually in degrees
    b. **Length of the arc** measures the size of a rounded feature along the rounded edge. This is usually a reference dimension.
    c. **Length of the chord** is the direct distance between the end points of the arc
3. **Radial dimensions** display the size of radii (the plural of radius). Discuss *shortened radii* and *true* and *spherical radii.*
4. **Coordinate dimensions** all begin at a particular point known as a *datum point*
    a. **Rectangular** coordinate dimensions start at some arbitrary datum point 0,0 and are noted in a Cartesian plane
    b. **Polar** coordinate dimensions start at some arbitrary datum point 0,0 and are noted in lengths of radii and angles of arcs
5. **Tabular** dimensions establish a table of references with a key that is tied to a drawing. This method reduces confusion by eliminating clutter in the body of the drawing.

B. Engineering Dimensions Conventions
1. Usually placed in the area that best shows the feature
2. Use of *dimension lines, leader lines,* and *extension lines*
3. **Working** dimensions are those used to control the size of the part
4. **Reference** dimensions are those used to contribute useful, but not essential, information to the machinist
5. **In-process** dimensions show the size of the part after a specific machine process, such as milling, but not the final size of the part. These dimensions are noted as such.
6. **Scale** shows the size of the drawing relative to the size of the part
7. **Tolerances** may be in the title block or noted in the drawing

C. Placement of Dimensions
1. **Chaining** shows the relationships between the details of features in a series; sometimes called *incremental dimensioning*
2. **Datum** dimensioning shows the details of features in relation to an arbitrary datum point 0,0; also called *absolute* or *base-line* dimensioning

        3. **Direct** dimensioning shows the relationship between two features where that relationship is completely independent of the rest of the part
III. Identify General Note Symbols
IV. Identify item number symbols
    A. Angular symbols
        1. ° indicates degrees
        2. ' indicates minutes
        3. " indicates seconds
        4. D or DIA indicates diameter
        5. R or RAD indicates radius
    B. Linear symbols
        1. ' indicates feet
        2. " indicates inches
        3. Metric linear abbreviations are not symbolic; they are alphabetical abbreviations. Discuss mm, cm, etc.
V. Locate Notes on a Print
    A. Dimensional: give specific values to sizes. Discuss conventions on *dual unit dimensioning.*
    B. Process
    C. Detail
    D. Single-view
    E. Thickness
VI. Interpret Commonly Used Abbreviations and Terminology
VII. Determine Tolerances Associated with Dimensions on a Drawing
    A. Discuss the differences in *standard* or *customary* tolerances and *specific* tolerances
    B. Discuss linear tolerance and radial tolerance
VIII. Determine the Tolerance for a Reference Dimension
IX. Determine the Surface Finish for a Given Part
    A. Definitions
        1. **Roughness**: the fine, irregular ridges/troughs caused by the finishing machine
        2. **Waviness**: the large, irregular ridges/troughs caused by the finishing machine. Roughness rides the surface of waviness.
        3. **Lay**: the predominant direction of the marks in the surface finish
        4. **Waviness Spacing:** the distance between the peaks of two adjacent ridges in the waviness
        5. **Waviness Height:** measured within a single waviness spacing, specifies the distance between the higher peak and the bottom of the trough
        6. **Roughness Spacing:** similar to waviness spacing, the distance between two adjacent peaks in the waviness

7. **Roughness Sampling Length:** the length of an arbitrary sample of the roughness, used to determine the roughness average
8. **Roughness Average:** the mathematical average of the roughness of a surface within a *roughness sampling length*, measured from a center line and measured in micro inches
9. Lay Symbols:
    - a. **Angular lay:** lay runs in two mutually perpendicular directions that are set at an angle that is oblique to the reference line
    - b. **Circular lay:** lay is basically circular around the center of the surface
    - c. **Multi-directional lay:** lay has no predominant direction
    - d. **Parallel lay:** lay is parallel to the reference line
    - e. **Particulate lay:** lay has no direction, is protuberant, or particulate
    - f. **Perpendicular lay:** lay is perpendicular to the reference line
    - g. **Radial lay:** lay is basically radial through the center of the surface

B. Basic and variant surface texture symbols
1. Basic checkmark with roughness indicators--maximum only and maximum/minimum values
2. Finish removal triangular checkmark with removal value
3. Already finished checkmark with tangential circle

X. List the Essential Components Found in the General Drawing Notes

CNC-C4-HO
List the Purpose of Each Type of Drawing
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Identify the purpose of orthographic (3 views) drawings;
b. Identify the purpose of isometric drawing;
c. Identify the purpose of exploded isometric drawing; and,
d. Identify the purpose of assembly drawings.

Module Outline:

NB: The Self-Assessment for this module is greatly dependent on the engineering drawings presented. Therefore, the instructor must complete the questions for the Self-Assessment. The editors strongly recommend a minimum of twenty questions for this module.

I. Identify the Purpose of Orthographic Views
    A. Any orthographic drawing must have a minimum of two views in order to show an object completely.
    B. The top view may be referred to as the plan view. The front or side views may be referred to as the elevations views.

II. Identify Positions of Views (Top, Front, Side, and Auxiliary)
    A. Top, is usually to the left and at the top of the print when viewing a single object, and represents the objects top if you were looking down at it.
    B. Front is directly below the top view, and on the same center line as the top. The front does not necessarily mean the actual front of the object.
    C. Side or sometimes referred as the right side is normally the right side of the front view and is on the same center lines as well as the same elevation.

III. Visualize One or More Views from a Given View
    A. In any given view the student can visualize more then one side of a object. The object can be shown in one of many positions.

IV. Identify Isometric Views
    A. Any object can be drawn from four different directions isometrically, but there is usually one view that best shows the object.
    B. When using isometrics the student should be familiar with the isometric axes, and the term preferred north and alternate north.
    C. In the isometric format, the lines of the object remain parallel and the object is drawn about the three isometric axes that are 120° degrees apart which is at 30° from the plane of the drawing.

D. Isometrics distort dimensions; therefore, you cannot draw isometrics to scale.

V. Identify Exploded Isometric Drawings

A. An *exploded drawing* is a picture of an assembly of several parts drawn isometrically to show the proper steps in assembling a unit.

VI. Identify Assembly Drawings

A. *Assembly drawings* are drawings in which the various parts of an object are shown in their relative positions in the completed unit.

B. Assembly drawings are also used:

1. To illustrate the proper working relationships of the mating parts of an object and the function of each.
2. To show a general idea of how the finished product should look.
3. To assist in securing overall dimensions and center lines in assembly.
4. To give the machinist data needed to design the smaller units of a larger object
5. To provide illustrations which may be used for maintenance manuals or other purposes.

CNC-C5-HO
Verify Drawing Elements
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Recognize out-of-date blueprints;
b. Check for revisions; and,
c. Determine the scale of the view or section.

Module Outline:

I. Recognize Out-of-Date Blueprints
    A. Check title block for date of completion (*Drawn By*)
    B. Check title block for date of certification (*Checked By*)
    C. Check title block for discontinuation (*Replaced By*)
    D. Check title block for what the new drawing replaces (*Replaces*)
II. Check for Revisions
    A. Revisions are usually listed in a separate block
    B. Revision (change) lists usually contain the following blocks:
        1. **Zone** (on large drawing sheets) shows the area of the revision, using an alphanumeric Cartesian plane
        2. **Revision** shows the exact location of the revision, usually by an alphabetic indicator
        3. **Description** gives a brief description of the change, such as a size change, a new part, or an angular cut difference
        4. **Date** indicates the date the revision was approved and became effective
        5. **Approved By** usually abbreviated, this block shows the person who approved the individual change
III. Determine the Scale of the View or Section
    A. Check the title block for the overall scale of the drawing
    B. Each detail view must be checked for scale
    C. Notes on scale
        1. **Full or 1:1**--the part is drawn to its actual size
        2. **Half** or **1/2:1**--the part is drawn to one-half its actual size
        3. Any other scale would be distinctly noted
IV. The Word *Noted* in Any Block Indicates That the Desired Information Can Be Found Written Somewhere on the Drawing, Usually Very Close to the Area to Which it Applies

CNC-C6-HO
Practice Geometric Dimensioning and Tolerancing (GD&T)
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Identify the purpose of GD&T;
b. Identify symbols for controlling location (or true position) of part features;
c. Identify symbols for controlling form (or alignment) of part features;
d. Identify symbols for showing datums and basic dimensions on drawings; and,
e. Identify symbols for Maximum Material Size (MMS) and Regardless of Feature Size (RFS).

Module Outline:

I. Identify the Purpose of GD&T
In industry today, there are many companies competing for replacement parts to replace ones that have worn out. They are geared more towards, and can handle, part replacement better than the companies that made the original unit. Realizing this, manufacturers and the engineering community have used Geometric Dimensioning and Tolerancing to maintain replacement part unity. For example, a part for your car was originally made by Mammoth Motor Company; but when you go to a parts house, they supply you with a part from Acme Auto Parts.

II. Identify Symbols for Controlling Location (Or True Position) of Part Features
True position, Concentricity, and *Symmetry* are used to indicate location control. Many units have a particular bolt pattern; if you were to replace one of the two units with another unit made from a different manufacturer, it may not have the same bolt pattern and would not be compatible.

III. Identify Symbols for Controlling Form (Or Alignment) of Part Features
Perpendicularity (squareness) is one example of form that must be controlled during manufacturing. The following list of symbols indicate types of form control:

1. Straightness;
2. Flatness;
3. Angularity;
4. Parallelism;
5. Roundness;
6. Cylindricity
7. Profile of any line;
8. Profile of any surface; and,

    9. Runout (circular or total).

IV. Identify Symbols for Showing Datums and Basic Dimensions on Drawings
Datums are reference points, lines, and planes taken to be exact for the purposes of calculation and measurement. They are placed in a rectangular frame and are identified by single or double letters. I, O, and Q are not used.

V. Identify Symbols for Maximum Material Condition (MMC) and Regardless of Feature Size (RFS)

  A. (MMC) refers to the maximum amount of material remaining.
  B. (RFS) refers to means that the form or position tolerance of a feature must be met no matter what the feature size is.

CNC-C7-HO
Analyze Bill of Materials (BOM)
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:
- a. Know which components are found on BOM;
- b. Determine which materials are needed to produce the part;
- c. Determine the quantities necessary to produce the part;
- d. Submit a completed stock request form as required; and,
- e. Submit a completed tool request form as needed.

Module Outline:

- I. Discuss Components Found on BOM
  - A. Item or Part Number, relative to the body of the drawing
  - B. Description of Item
  - C. Specification
  - D. Material Needed
  - E. Number Required
- II. Determine Materials Needed to Produce the Part
- III. Determine Quantities Necessary to Produce the Part
- IV. Submit Completed Stock Request Form as Required
  This topic is company-specific and must be designed at such level. The instructor is encouraged to be extremely general in comments, covering only those areas of stock requests that are universal in application.
- V. Submit Completed Tool Request Form as Needed
  Here, too, the instructor must generalize and emphasize that s/he is generalizing.

CNC-C8-HO
Describe the Relationship of Engineering Drawings to Planning
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Discuss production schedules;
b. Understand Material Resource Planning (MRP);
c. Recognize and utilize inventory control records; and,
d. Recognize and follow specific shop floor routing documents.

Module Outline:

I. Discuss Production Schedule
    A. Internal Factors
        1. Available personnel and equipment
        2. Priority
        3. Setup time
        4. Parts per man-hour (quotas)
        5. Warehouse to shop floor time for stock
        6. Shop floor to shipping department time for parts
    B. External factors
        1. Customer deadlines
        2. Material delivery schedules
II. Discuss Material Resource Planning (MRP)
    A. Volume of production
    B. Required stock
        1. Types of stock needed
        2. Amounts of stock needed
    C. Waste management
    D. Mechanical management
        1. Tool wear and replacement
        2. Machine down-time
III. Discuss Inventory Control Records
    A. Receipt of goods documents
    B. Waste management documents
    C. Return of goods documents
    D. Tool room accounts and documents
    E. Machine time documents
IV. Discuss Shop Floor Routing Documents
    These documents vary in detail from shop to shop. The instructors should use documents from their own shops to explain both the theory and practice of routing documents.

CNC-C9-HO
Understand and Use Quality Systems
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:
- a. Understand and apply quality principles, including continuous improvement; and,
- b. Document paper trails for part revisions.

Module Outline:

- I. Understand and Apply Quality Principles, Including Continuous Improvement
  - A. Tolerances as basic quality control
  - B. The machinist as the first line of excellence
  - C. Specific systems
    These systems are diverse. You, as the instructor, must tailor this portion of the lecture to the system used in your circumstances.
  - D. The inspector as guarantor
  - E. The consumer: the ultimate judge of top quality
- II. ISO 9000
  - A. Purpose
  - B. What is ISO 9000?
  - C. How does is work?
  - D. Where do the standards come from?
  - E. Who uses this stuff, anyway?
- III. Document Paper Trails for Part Revisions

CNC-C10-HO
Verify Standard Requirements
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:

- a. Discuss the purpose of standards; and,
- b. Discuss source locations for standards.

Module Outline:

- I. Discuss the Purpose of Standards
  - A. What are standards, anyway?
  - B. Why have standards at all?
  - C. How does a technician use today's standards?
  - D. The technician's role in quality as it relates to standards.
- II. Discuss Source Locations for Standards
  - A. Shop/company sources—*Machinery's Handbook,* especially
  - B. Industry sources
  - C. Governmental sources
- III. Oral Shorthand—Nominal Sizes vs. Actual Sizes

CNC MACHINIST .... **programs, edits, sets up, and operates CNC lathes, mills and grinders to perform machining operations necessary to produce workpieces to referenced engineering standards.**

	Duties	Tasks												
A	Practice Safety	A-1 Follow safety manuals and all safety regulations/ requirements	A-2 Use protective equipment	A-3 Follow safe operating procedures for hand and machine tools	A-4 Maintain a clean and safe work environment	A-5 MSDS/ control chemical hazards								
B	Apply Mathematical Concepts	B-1 Perform basic arithmetic functions	B-2 Convert fractions/ decimals	B-3 Convert Metric/ English measurements	B-4 Perform basic algebraic operations	B-5 Use practical geometry	B-6 Understand basic trigonometry	B-7 Calculate speeds and feeds for machining	B-8 Use coordinate systems					
C	Interpret Engineering Drawings and Control Documents	C-1 Identify basic layout of drawings	C-2 Identify basic types of drawings	C-3 Review blueprint notes and dimensions	C-4 List the purpose of each type of drawing	C-5 Verify drawing elements	C-6 Practice Geometric Dimensioning and Tolerancing (GD&T)	C-7 Analyse bill of materials (BOM)	C-8 Describe the relationship of engineering drawings to planning	C-9 Understand and use quality systems	C-10 Verify standard requirements			
D	Recognize Different Manufacturing Materials and Processes	D-1 Identify materials with desired properties	D-2 Identify materials and processes to produce a part	D-3 Describe the heat treating process	D-4 Test metal samples for hardness	D-5 Understand welding operations								
E	Measure/ Inspect	E-1 Understand metrology terms	E-2 Select measurement tools	E-3 Measure with hand held instruments	E-4 Eliminate measurement variables	E-5 Measure/ inspect using surface plate and accessories	E-6 Inspect using stationary equipment							
F	Perform Conventional Machining	F-1 Prepare and plan for machining operations	F-2 Use hand tools	F-3 Operate power saws	F-4 Operate drill presses	F-5 Operate vertical milling machines	F-6 Operate horizontal milling machines	F-7 Operate metal cutting lathes	F-8 Operate grinding/ abrasive machines					
G	Perform Advanced Machining	G-1 Understand CNC basics	G-2 Program CNC machines	G-3 Operate CNC machining centers (mills)	G-4 Operate CNC turning centers (lathes)									
H	Use Verification and Communication Systems	H-1 Use personal computer	H-2 Use various operating systems	H-3 Use computer communications systems	H-4 Use verification systems	H-5 Use the Internet								
I	Program Using CAM System	I-1 Understand CAD/ CAM programs	I-2 Manipulate CAD functions	I-3 Process simple tool-path data	I-4 Create advanced surface models	I-5 Process complex tool-path functions								

CNC-D1-HO1
Identify Materials with Desired Properties
Attachment 1: MASTER Handout No. 1

Objective(s):

Upon completion of this unit the student will be able to:
- a. Discuss classification system for metals; and,
- b. Describe general characteristics for carbon steels, tool steels, stainless steels, structural steels, cast irons, aluminum, and other commonly used metals.

Module Outline:

- I. Discuss the Physical Properties of Metal
  - A. Brittleness - the property of a metal which permits no permanent distortion before breaking
  - B. Ductility - the ability of the metal to be permanently deformed without breaking
  - C. Elasticity - the ability of a metal to return to its original shape after any force acting upon it has been removed
  - D. Hardness - the resistance to forcible penetration
  - E. Malleability - the property of a metal which permits it to be hammered or rolled into other sizes and shapes
  - F. Tensile strength - the maximum amount of pull that a material will withstand before breaking
  - G. Toughness - the property of a metal to withstand shock or impact
- II. Discuss the Classification System for Steel
  - A. Carbon steels
    - 1. Low carbon steel - contains from 0.02 to 0.20 percent of carbon
    - 2. Medium carbon steel - contains from 0.30 to 0.60 percent of carbon
    - 3. High carbon steel (tool steel) - contains over 0.60 percent of carbon
  - B. Alloy steels - alloying elements allow steels to possess special characteristics
    Discuss Table 1.1 "Effects of Alloying Elements on Steel"
    Discuss Table 1.2 "SAE-ANSI Numerical Designation of Alloy Steels"
- III. Describe General Characteristics For:
  - A. Carbon Steels
  - B. Tool Steels
  - C. Stainless Steels
  - D. Structural Steels
  - E. Cast Irons

F. Non-Ferrous Metals
  1. Aluminum and Its Alloys
  2. Copper and Its Alloys
  3. Nickel Alloys
  4. Precious Metals
  5. Others

CNC-D1-HO2
Identify Materials With Desired Properties
Attachment 2: **MASTER** Handout No. 2

TABLES FOR CNC-D1 — PROPERTIES OF METALS
TABLE 1.1

THE EFFECT OF ALLOYING ELEMENTS ON STEEL

EFFECT	ELEMENT											
	Carbon	Chromium	Cobalt	Lead	Manganese	Molybdenum	Nickel	Phosphorus	Silicon	Sulfur	Tungsten	Vanadium
Increases tensile strength	X	X			X	X	X					
Increases hardness	X	X										
Increases wear resistance	X	X			X		X				X	
Increases hardenability	X	X			X	X	X					X
Increases ductility					X							
Increases elastic limit		X				X						
Increases rust resistance		X					X					
Increases abrasion resistance		X			X							
Increases toughness		X				X	X					X
Increases shock resistance		X					X					X
Increases fatigue resistance												X
Decreases ductility	X	X										
Decreases toughness			X									
Raises critical temperature		X	X								X	
Lowers critical temperature					X		X					
Causes hot shortness										X		
Causes cold shortness								X				
Imparts red hardness			X			X					X	
Imparts fine grain structure					X							X
Reduces deformation					X		X					
Acts as deoxidizer					X				X			
Acts as desulphurizer					X							
Imparts oil hardening properties		X			X	X	X					
Imparts air hardening properties					X	X						
Eliminates blow holes								X				
Creates soundness in casting									X			
Facilitates rolling and forging					X				X			
Improves machinability				X						X		

TABLE 1.2

SAE-AISI NUMERICAL DESIGNATION OF ALLOY STEELS *(X Represents Percent of Carbon in Hundredths)*	
Carbon Steels	
Plain carbon	10xx
Free-cutting, resulfurized	11xx
Manganese Steels	13xx
Nickel Steels	
.50% nickel	20xx
1.50% nickel	21xx
3.50% nickel	23xx
5.00% nickel	25xx
Nickel-Chromium Steels	
1.25% nickel, .65% chromium	31xx
1.75% nickel, 1.00% chromium	32xx
3.50% nickel, 1.57% chromium	33xx
3.00% nickel, .80% chromium	34xx
Corrosion and heat-resisting steels	303xx
Molybdenum Steels	
Chromium	41xx
Chromium-nickel	43xx
Nickel	46xx and 48xx
Chromium Steels	
Low-chromium	50xx
Medium-chromium	511xx
High-chromium	521xx
Chromium-Vanadium Steels	6xxx
Tungsten Steels	7xxx and 7xxxx
Triple-Alloy Steels	8xxx
Silicon-Manganese Steels	9xxx
Leaded steels	11Lxx (example)

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CNC-D2-HO
Identify Materials and Processes to Produce a Part
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Briefly describe and list the advantages and disadvantages for each of the following: casting processes, hot working processes, and cold working processes;
b. Discuss service requirements (strength, hardness, etc.);
c. Discuss fastening processes (fasteners, welding, bonding, etc.); and,
d. Discuss corrosion resistance methods.

Module Outline:

I. Describe Casting Processes
   A. Discuss the following casting processes: sand, evaporative, shell molding, permanent mold, centrifugal, investment, and die casting
   B. Discuss pattern and mold design factors for each of the above casting processes
   C. List the advantages and disadvantages of the casting processes
II. Describe Hot Working Processes
   A. Discuss the following hot working processes: rolling, strand casting, forging, drawing, extrusion, spinning, and roll forming
   B. List the advantages and disadvantages of the hot working processes
III. Describe Cold Working Processes
   A. Discuss the following cold working processes: rolling, blanking, pressing, drawing, extruding, wire and bar drawing, bending, shearing, and roll forming
   B. List the advantages and disadvantages of the cold working process
IV. Evaluate Alternative Manufacturing Processes
   A. Discuss the powder metallurgy process (PM)
   B. Discuss the following nontraditional machining processes: EDM, laser machining, ultrasonic machining, hydrojet machining, electron beam machining, and plasma beam machining

CNC-D3-HO
Describe the Heat Treating Process
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Discuss the reasons for heat treating;
b. Discuss the time/temperature chart;
c. List the different quenching media;
d. Estimate metal heat temperature by color; and,
e. List reasons for stress relieving workpieces.

Module Outline:

I. Discuss the Reasons for Heat Treating
   A. Hardening for utility
   B. Tempering for toughness without brittleness
II. Discuss the Time/Temperature Chart
III. List the Different Quenching Media (In order of *severity* or speed of quenching)
   A. Brine (water and sodium chloride or sodium hydroxide)
   B. Water
   C. Fused (liquid) salts
   D. Molten lead
   E. Soluble oil and water
   F. Oil
   G. Air
IV. Estimate Metal Heat Temperature by Color
   A. Use of the temper color chart for tempering

Temperature (F)	Temperature (C)	Oxide Color	Suggested Uses
425	220	Light Straw	Steel-cutting tools
462	240	Dark Straw	Punches & Dies
490	258	Gold	Shear blades
500	260	Purple	Wood-cutting tools
540	282	Violet	Screwdrivers
580	304	Pale Blue	Springs
620	327	Steel Grey	None

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  - B. *Chicken Wire* markings warn of overheating.
- V. List Reasons for Stress Relieving Workpieces
  - A. Increased machinability
  - B. Increased workability in cold processes
- VI. Special Safety Concerns of Heat Treating
  - A. Protective Gear against. . .
    - 1. Heat
    - 2. Fumes
    - 3. Concussion
  - B. Toxicity of Certain Media
- VII. Special Problems in Heat Treating
  - A. Brittleness
  - B. Distortion
  - C. Discoloration (sometimes unimportant)
  - D. Inadvertent heat treating

CNC-D4-HO
Test Metal Samples for Hardness
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Perform file test to test for metal hardness;
b. Use other tests to identify metals; and,
c. Perform Rockwell hardness tests.

Module Outline:

I. Perform File Test to Test for Metal Hardness
  A. Imprecise method, good for rough estimates only
  B. Requires more experienced machinist
II. Use Other Tests to Identify Metals
  A. High-carbon steels show more spark bursts than do low-carbon steels.
  B. Non-ferrous metals
    1. Aluminum
    2. Magnesium
    3. Brass
    4. Bronze
    5. Nickel
    6. Tin
    7. Others
III. Perform Rockwell Hardness Tests
  A. Ferrous metals
  B. Non-ferrous metals
IV. Perform Brinell Hardness Tests
  A. Ferrous metals
  B. Non-ferrous metals
V. Other Hardness Tests as Specified by the Instructor
  A. Ferrous metals
  B. Non-ferrous metals

Test Metal Samples for Hardness

Attachment 2: **MASTER** Laboratory Exercise

I. The instructor should demonstrate the aluminum/magnesium test using the zinc chloride solution.
II. Each student should receive eye or full face protection and three to five samples for evaluation.
III. Each sample should be file-tested.
IV. Each sample should be spark-tested.
V. Each sample should be tested for hardness on the Rockwell tester.

RESULTS OF TESTS

Record your answers on the following charts. Under "Characteristics," write what you saw (spark length, color, etc.) or felt (resistance, heating, etc.) during the test.

FILE TEST

Sample	Characteristics	Preliminary Identification
1		
2		
3		
4		
5		

SPARK TEST

Sample	Characteristics	Preliminary Identification
1		
2		
3		
4		
5		

ROCKWELL HARDNESS TEST

Sample	Rockwell Hardness Number	Preliminary Identification
1		
2		
3		
4		
5		

BRINELL HARDNESS TEST

Sample	Brinell Hardness Number	Preliminary Identification
1		
2		
3		
4		
5		

OTHER HARDNESS TEST

Sample	Hardness Designation	Preliminary Identification
1		
2		
3		
4		
5		

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    - a. No loose clothing, including ties;
    - b. Long hair properly stowed;
    - c. No jewelry;
    - d. Hard, closed-toe shoes;
    - e. Eye protection (safety glasses); and,
    - f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

CNC-D5-HO
Understand Welding Operations
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Perform the basic SMAW process;
b. Perform the basic oxyacetylene cutting and welding process;
c. Perform the basic GTAW (Heliarc) process; and,
d. Perform the basic GMAW (MIG) process.

Module Outline:

DON'T CARRY A BOMB IN YOUR POCKET!

NEVER carry a butane lighter into a welding area. These are mini-Molotov cocktails.

I. Safety Procedures Specific to the Welding Process
   A. Specific safety precautions must be taken to ensure a proper breathing atmosphere in all welding areas.
      1. Weld only in ventilated areas. Welding shielding gases can displace the air needed for breathing. These gases are odorless and colorless, and most are heavier than air.
      2. Weld in a position that will allow your head to be out of the welding plume, but will still give a good view of the welding arc. The welding plume could contain harmful fumes and gases.
      3. Provide enough ventilation wherever welding and cutting are performed. Welding in confined spaces may require special procedures, such as the use of an air-supplied hood or hose mask.
      4. Do not weld on dirty plate or plate contaminated with an unknown material. The fumes and gases which are formed could be hazardous to health.
   B. Electrical shock can be avoided by following specific safety precautions.
      1. Do not touch live electrical parts.
      2. Ground all electrical equipment and the work-piece to prevent accidental electrical shocks.
      3. Use the correct welding cable size for both the ground lead and the welding lead. Sustained overloading will cause cable failure and result in possible electrical shock or fire hazard.

    4. *Be sure all electrical connections are tight, clean, and dry.* Poor electrical connections can heat up and even melt, causing dangerous arcs and sparks.
    5. Keep dry. Moisture and water can conduct electricity. Fix water leaks immediately.
    6. Keep welding cables and connectors in good condition. Improper or worn electrical connections can cause short circuits and can increase the chance of an electrical shock.
    7. Avoid open-circuit voltage. Open-circuit voltage is much higher than welding voltage.
    8. Shut off electrical power when working on welding equipment.

C. Ultraviolet and infrared rays emitted by the welding arc, as well as the spatter from the welding arc, can injure eyes and burn skin. Specific safety precautions must be followed to ensure adequate protection.
    1. Wear 100% cotton clothing. It will not catch fire easily, it offers good protection from light welding spatter, and it is cooler in the summer and warmer in the winter.
    2. Cover all skin surfaces. Keep shirt sleeves rolled down.
    3. Wear cuffless pants to eliminate spatter traps.
    4. Wear leather boots. Pant legs should cover boot tops.
    5. Wear clean clothing. Oil- and grease-stained clothes will tend to ignite from welding spatter.
    6. For more severe welding conditions, wear protective clothing such as heat resistant jackets, aprons, and leggings.
    7. Wear safety glasses to protect from arc flashes, mechanical injury, or other mishaps.
    8. Wear ear protection, not only where there is noise but where there is a chance that spatter or sparks could get into the ears.
    9. Wear a 100% cotton cap to protect the head from sparks or spatter.
    10. Wear long-gauntlet leather gloves.
    11. Do not touch hot metal with bare hands. Use tongs or pliers and wear leather gloves.
    12. Protect nearby workers from exposure to the welding arc by putting up shields.
    13. Wear a welding helmet with the correct shade of welding lens. Choose the correct lens from a filter recommendations table (See Figure 1).

FILTER RECOMMENDATIONS
(adapted from ANSI Safety Standard Z49.1-88)
SMAW

Application	Minimum Shade No.	Suggested Shade*
Less than 60 amps	7	9
60 to 160 amps	8	10
160 to 250 amps	10	12
250 to 500 amps	11	14

* As a general rule, start with a shade that is too dark to see the arc zone. Then go to the next lighter shade until you find one which gives you sufficient view of the arc zone without exerting a strain on your eyes.

FIGURE 1 FILTER RECOMMENDATIONS

D. Specific precautions must be taken to ensure that there is no loss of property due to welding sparks, spatter, and heat.
  1. If possible, weld in specially designated areas or enclosures of noncombustible construction.
  2. Remove combustibles from the work area by at least 35 feet if possible.
  3. Cover combustibles that cannot be removed from the welding area with tight-fitting, flame-resistant material. Items that should be covered include combustible walls, floors, ceilings, and any cracks or other openings that might let a spark pass through it.
  4. If welding is to be performed on or adjacent to a metal wall, ceiling, or partition, move combustibles on the other side to a safe location.
  5. If combustibles cannot be adequately sealed off or removed, station a fire watcher at that location. The fire watcher must have adequate fire extinguishing capabilities.
  6. Do not weld on materials having either a coating or internal structure that is combustible.
  7. Place hot scrap and slag in non-combustible containers.
  8. Ensure that fire extinguishers are available nearby.

9. Conduct a thorough examination for evidence of a fire before leaving the work area, and continue a fire check for at least 30 minutes after the welding operation has been completed.
10. Follow all company safety procedures regarding welding in hazardous areas.

E. Specific Safety Precautions for Oxyacetylene Equipment

CAUTION: Specific preventive and protective safety measures must be followed when using oxyacetylene equipment:

1. Use goggles or shield with a number five shade.
2. Wear gloves, long sleeve shirts, pants of high cotton or wool content, leather boots, and soft cotton caps.
3. When lighting the torch, direct the torch away from yourself and other personnel.
4. Never leave a lit torch unattended. When leaving your work station, always extinguish your torch.
5. Never use matches or butane lighters for lighting a torch. Only use spark or friction lighters.
6. Never cut on containers that have contained flammable or toxic substances.
7. Either move work away from or protect wooden or other flammable materials which may be close to the work.
8. When cutting, cover concrete floors with sheet metal where sparks and molten metal are being directed.
9. Before beginning to work, locate the nearest fire alarm and the nearest fire extinguisher.
10. Cut in a well-ventilated area. If adequate ventilation is not possible, use a respirator.
11. Keep all petroleum products away from oxyacetylene equipment and operations. The combination of pure oxygen and oil is explosive.

F. Specific Safety Precautions for Acetylene and Oxygen Cylinders

CAUTION: Handle acetylene and oxygen cylinders carefully:

1. Keep acetylene operating pressures at or below 15 psi.
2. Open the acetylene cylinder valve one-half to one full turn when using a portable rig to be sure that the cylinder can be quickly turned off in the event of burn-back or a fire at a leak in the hose or at a connection.
3. Do not open the acetylene torch valve where acetylene could flow into a bucket or other container and cause a fire.
4. Never attempt to connect an acetylene hose to an oxygen torch connection. Damage to the torch or an explosion could result. Acetylene hoses are colored red and acetylene fittings are left-hand threaded and usually notched.
5. Never use oxygen or fuel gas from a cylinder except through an approved pressure-reducing regulator.

6. Do not use pipe-fitting compounds or thread lubricants for making connections.
7. Never use a cylinder that is leaking.
8. Store and transport cylinders in the upright position.
9. Secure all cylinders with chain when storing, transporting, or using, to prevent them from being turned over by accident.
10. Never tamper with fusible plugs or other safety devices on cylinders.
11. To open and close acetylene cylinder valves not provided with hand-wheels, always use the special wrench or key. When cutting, leave the key in place for rapid shutdown in case of fire.
12. Never use any cylinder, full or empty, as a roller or support.
13. Never use oxygen as though it were compressed air.
14. Do not handle oxygen cylinders on the same platform with oil.
15. Never use wire-rope slings or electromagnets for lifting cylinders. Do not lift cylinders by the protective cap alone.
16. Store oxygen cylinders separately from fuel gas cylinders.
17. Always keep empty cylinders separate from full cylinders.
18. Mark all empty cylinders as such after use.
19. Keep all cylinders stored inside buildings at least 20 feet away from combustible materials.
20. Never bring any arc or flame close to or directly into contact with a cylinder.
21. Never exceed the maximum safe withdrawal rate for acetylene cylinders (one seventh of the cylinder's *current* contents per hour). If acetylene is withdrawn from the cylinder at a greater rate, acetone will also be withdrawn from the cylinder, damaging the cutting equipment. If additional flow is needed, then manifold the required number of cylinders together.

G. Specific Safety Precautions for Regulator Burnout (R.B.O.)

CAUTION: Avoid potentially deadly regulator burnout (R.B.O.). Regulator burnout is a spontaneous explosion that happens when a torch is being lit. To minimize the risk of R.B.O., follow these safety precautions:

1. "Crack" the oxygen cylinder valve (open it slightly) before attaching the regulator. Stand to one side or the rear of the cylinder outlet. Open the cylinder valve slightly for an instant and then close it to clean the valve of dust and dirt which may have accumulated during storage. Dirt can damage an oxygen regulator and may cause R.B.O.
2. Use only oxygen regulators to control oxygen supply. A pressure-reducing regulator must be connected to the oxygen cylinder valve. Make certain the regulator is clean, free of grease and oil, and has a clean filter installed in its inlet nipple.

Oil, grease, coal dust, and other combustibles can cause regulator burnouts. Never use an oxygen regulator for other gases.

3. Before opening an oxygen cylinder valve, make sure the oxygen regulator pressure-adjusting screw is released. This is done by rotating the screw counterclockwise until it turns freely. This closes the regulator valve and prevents damage due to a sudden pressure surge.
4. While opening the oxygen cylinder valve, stand to one side of the oxygen regulator. Do not stand in line with the front or the back of the pressure-adjusting screw. Open the cylinder valve as slowly as possible, until the high pressure gauge reaches cylinder pressure. Never open a cylinder valve suddenly. Sudden surges of high pressure can cause R.B.O.

II. Describe the SMAW Process

Shielded Metal Arc Welding is a welding process which joins metals by heating them with an arc between a covered metal electrode and the metals being joined. Shielding is obtained from the decomposition (breakdown) of the electrode covering. Pressure is not used and filler metal is obtained from the electrode. The electric arc flowing across an air gap produces very intense heat and light. An electric arc has been measured at 10,000°F. Considering that steel melts at around 2800°F, the electric arc is indeed a very fast and efficient heat source for melting steel when welding.

III. Describe the Oxyacetylene Cutting and Welding Process

Oxyacetylene cutting requires the use of specific procedures and specific techniques in order to work safely and to produce acceptable cuts. Proper flame adjustments, torch angles, and flame-to-work distances must be maintained in order to produce good cuts. Oxyacetylene cutting can be done from both fixed cutting stations and from portable cutting stations.

The key operations to oxyacetylene cutting are as follows:

1. Prepare to cut.
2. Light the torch.
3. Cut metal with the torch.
4. Extinguish the torch.

HOW TO SELECT THE CORRECT NUMBER OF ACETYLENE CYLINDERS

To determine the number of cylinders required for proper manifold operation, follow the guidelines below:

1. The number of cylinders in the manifold is determined by the volume of gas in cubic feet per hour required. Determine the cubic feet per hour required for the largest tip used and multiply that by the number of torches or stations in operation at the same time. This will give the total volume of each gas required per hour.
2. The manifold should have enough cylinders to provide a minimum of one day's requirements.
3. Maximum acetylene withdrawal for continuous operation is 1/7 (of 14%) of each cylinder capacity per hour. The chart allows for 7.8% excess capacity.

CFH acetylene withdrawal per hour required	Number of 300 cubic foot cylinders per manifold
40	1
80	2
120	3
160	4
200	5
240	6
280	7
320	8
360	9
400	10
440	11
480	12
520	13
560	14
600	15
640	16
680	17
720	18
760	19
800	20

Acetylene Cylinder Manifold Guide

IV. Describe the GTAW (Heliarc) Process
V. Describe the GMAW (MIG) Process
VI. Describe the Band/Flash Welding Machine and Process

CNC-D5-LE
Understand Welding Operations
Attachment 2: MASTER Laboratory Exercise

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1. The instructor will demonstrate each of the following processes:
    a. Basic SMAW process;
    b. Basic oxyacetylene cutting and welding process;
    c. Basic GTAW (Heliarc) process; and,
    d. Basic GMAW (MIG) process.

2. The students will practice each of the following processes:
    a. Basic SMAW process;
    b. Basic oxyacetylene cutting and welding process;
    c. Basic GTAW (Heliarc) process; and,
    d. Basic GMAW (MIG) process.

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

CNC MACHINIST .... **programs, edits, sets up, and operates CNC lathes, mills and grinders to perform machining operations necessary to produce workpieces to referenced engineering standards.**

	Duties	Tasks												
A	**Practice Safety**	A-1 Follow safety manuals and all safety regulations/ requirements	A-2 Use protective equipment	A-3 Follow safe operating procedures for hand and machine tools	A-4 Maintain a clean and safe work environment	A-5 MSDS/ control chemical hazards								
B	**Apply Mathematical Concepts**	B-1 Perform basic arithmetic functions	B-2 Convert fractions/ decimals	B-3 Convert Metric/ English measurements	B-4 Perform basic algebraic operations	B-5 Use practical geometry	B-6 Understand basic trigonometry	B-7 Calculate speeds and feeds for machining	B-8 Use coordinate systems					
C	**Interpret Engineering Drawings and Control Documents**	C-1 Identify basic layout of drawings	C-2 Identify basic types of drawings	C-3 Review blueprint notes and dimensions	C-4 List the purpose of each type of drawing	C-5 Verify drawing elements	C-6 Practice Geometric Dimensioning and Tolerancing (GD&T)	C-7 Analyze bill of materials (BOM)	C-8 Describe the relationship of engineering drawings to planning	C-9 Understand and use quality systems	C-10 Verify standard requirements			
D	**Recognize Different Manufacturing Materials and Processes**	D-1 Identify materials with desired properties	D-2 Identify materials and processes to produce a part	D-3 Describe the heat treating process	D-4 Test metal samples for hardness	D-5 Understand welding operations								
E	**Measure/ Inspect**	E-1 Understand metrology terms	E-2 Select measurement tools	E-3 Measure with hand held instruments	E-4 Eliminate measurement variables	E-5 Measure/ inspect using surface plate and accessories	E-6 Inspect using stationary equipment							
F	**Perform Conventional Machining**	F-1 Prepare and plan for machining operations	F-2 Use hand tools	F-3 Operate power saws	F-4 Operate drill presses	F-5 Operate vertical milling machines	F-6 Operate horizontal milling machines	F-7 Operate metal cutting lathes	F-8 Operate grinding/ abrasive machines					
G	**Perform Advanced Machining**	G-1 Understand CNC basics	G-2 Program CNC machines	G-3 Operate CNC machining centers (mills)	G-4 Operate CNC turning centers (lathes)									
H	**Use Verification and Communication Systems**	H-1 Use personal computer	H-2 Use various operating systems	H-3 Use computer communications systems	H-4 Use verification systems	H-5 Use the Internet								
I	**Program Using CAM System**	I-1 Understand CAD/ CAM programs	I-2 Manipulate CAD functions	I-3 Process simple tool-path data	I-4 Create advanced surface models	I-5 Process complex tool-path functions								

CNC-E1-HO
Understand Metrology Terms
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

- a. Discuss the use of metrology in manufacturing;
- b. Discuss the Inch system of measurement;
- c. Discuss the Metric system of measurement;
- d. Discuss semi-precision and precision measurement; and,
- e. Discuss the following: precision, reliability, discrimination, and accuracy.

Module Outline:

- I. Discuss the Use of Metrology in Manufacturing
    - A. Discuss the function and reason for measurements in manufacturing
    - B. Discuss the changes (metrology related) in manufacturing today
        - 1. Interchangeable manufacture
        - 2. World trade
        - 3. High precision
- II. Discuss the Inch System of Measurement
    - A. Discuss fractional (scale) dimensions for linear measurement
    - B. Discuss decimal dimensions for linear measurement
    - C. Convert fractional to decimal
        - 1. Review mathematical conversion method
        - 2. Fractional/decimal conversion charts
    - D. Practice and demonstration of skills listed above
- III. Discuss the Metric System of Measurement
    - A. Discuss the units of measure commonly used in the metric system
    - B. Convert inch to metric
        - 1. Review mathematical method (1 inch = 25.4 mm)
        - 2. Conversion charts
    - C. Practice and demonstration of skills listed above
- IV. Discuss Semi-Precision and Precision Measurement
    - A. Discuss the difference between semi-precision and precision measurement
        - 1. Semi-precision measurements are 1/64" (.5mm) or greater
        - 2. Precision measurements are less than 1/64" (.5mm)
    - B. Discuss the five categories of precision measurement
        - 1. Outside measurement
        - 2. Inside measurement
        - 3. Depth measurement

        4. **Thread measurement**
        5. **Height measurement**

V. **Discuss the Following Measurement Terms: Accuracy, Precision, Reliability, and Discrimination**
- A. ***Accuracy*** **- whether or not something is made according to standard. (The standard for manufacturing is the blueprint.)**
- B. ***Precision*** **- the degree of exactness required for an application or design requirement**
- C. ***Reliability*** **- the ability to consistently obtain the desired result**
- D. ***Discrimination*** **- the degree that a measuring instrument divides its basic unit of length**

CNC-E2-HO
Select Measurement Tools
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Identify basic semi-precision measuring tools;
b. Identify precision measuring tools;
c. Justify use of particular measurement tools based on tool characteristics;
d. Identify error possibilities in measurement tool selection; and,
e. Demonstrate proper care of precision measuring tools.

Module Outline:

I. Describe and Discuss the Following Semi-Precision Measuring Tools
   A. Steel rules
   B. Calipers
   C. Squares
II. Describe and Discuss the Following Precision Measuring Tools
   A. Micrometers (outside, inside and depth)
   B. Verniers (calipers and height gage)
   C. Gages (small hole, telescope, fixed, and dial bore)
III. Justify Use of Particular Measurement Tools Based on Tool Characteristics
   A. What tolerance is required by the print?
   B. What physical characteristics of the part influence tool selection?
   C. What is the discrimination of the tool?
   D. How much time is available for part measurement/inspection?
   E. Will the tool be used by itself or in conjunction with some other tool?
   F. What is the most reliable tool for this application?
IV. Identify Error Possibilities in Measurement Tool Selection
   A. Part not being produced to specifications
   B. Too much time spent trying to measure correctly by not having the right tool
V. Demonstrate Proper Care of Precision Measuring Tools
   A. Storage
   B. Handling
   C. Cleaning

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

CNC-E3-HO
Measure With Hand Held Instruments
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

- a. Measure with steel rules (metric and inch);
- b. Measure with micrometers;
- c. Measure with comparison measuring instruments (e.g., calipers, telescope gages);
- d. Measure with direct measuring instruments (e.g., vernier, dial and digital instruments); and,
- e. Measure with fixed gages (go and no-go gages).

Module Outline:

- I. Discuss the Importance of Learning and Practicing Proper Measurement Techniques
  - A. Show the video "Measuring Tools"
  - B. Give each student a copy of the handout "Proper Measuring Techniques"
- II. Discuss and Demonstrate Proper Measurement Techniques Using the Steel Rule
- III. Discuss and Demonstrate the Use of Micrometer Type Measuring Instruments
  - A. Outside micrometers
  - B. Inside micrometers
  - C. Depth micrometers
  - D. Practice and demonstration of skills listed above
- IV. Discuss and Demonstrate the Use of Transfer Type Measuring Instruments
  - A. Spring calipers (inside and outside)
  - B. Telescope gages
  - C. Small hole gages
  - D. Practice and demonstration of skills listed above
- V. Discuss and Demonstrate the Use of Direct Measuring Instruments
  - A. Vernier calipers
  - B. Dial calipers
  - C. Digital calipers
  - D. Practice and demonstration of skills listed above
- VI. Discuss the Purpose of Fixed Gages and Demonstrate Their Use
  - A. Cylindrical plug and ring gages
  - B. Taper plug and ring gages
  - C. Snap gages

    D. **Thread plug gages**
    E. **Practice and demonstration of skills listed above**

VII. **Complete Practical Exercise (CNC-E3-LE1) and (CNC-E3-LE2) On All the Above Material**

Name:________________   Date:______________________

CNC-E3-LE1
Measure With Hand Held Instruments
Attachment 2: MASTER Laboratory Exercise No. 1

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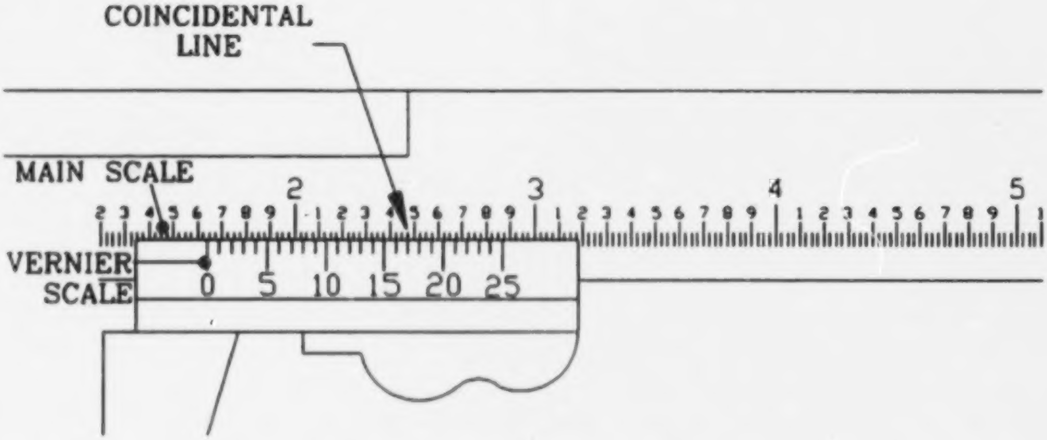
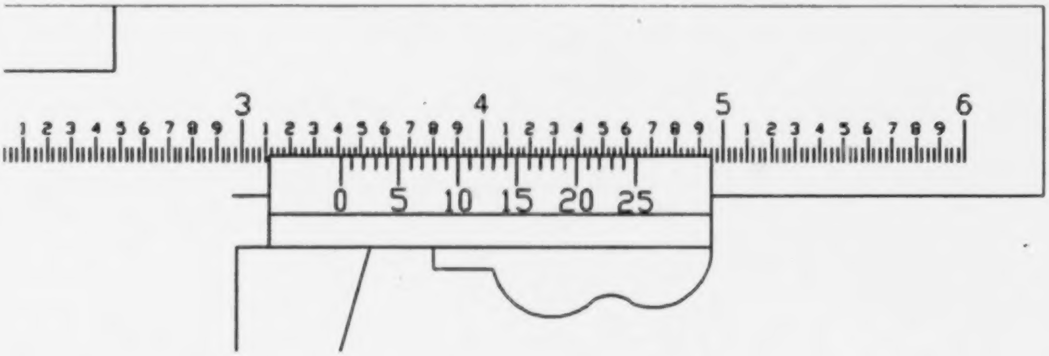
1. What is the reading on the vernier caliper below?
   a. .642
   b. 1.642
   c. 1.645
   d. 1.64


COINCIDENTAL LINE
MAIN SCALE
VERNIER SCALE
2
3
4
5
2 3 4 5 6 7 8 9 1 2 3 4 5 6 7 8 9 1 2 3 4 5 6 7 8 9 1 2 3 4 5 6 7 8 9 1
0
5
10
15
20
25

2. What is the reading on the vernier caliper below?
   a. .415
   b. 3.125
   c. 3.405
   d. 3.412


3
4
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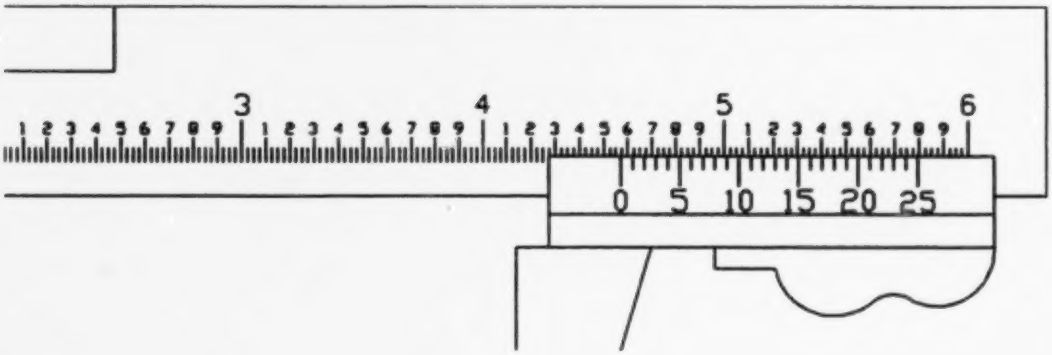
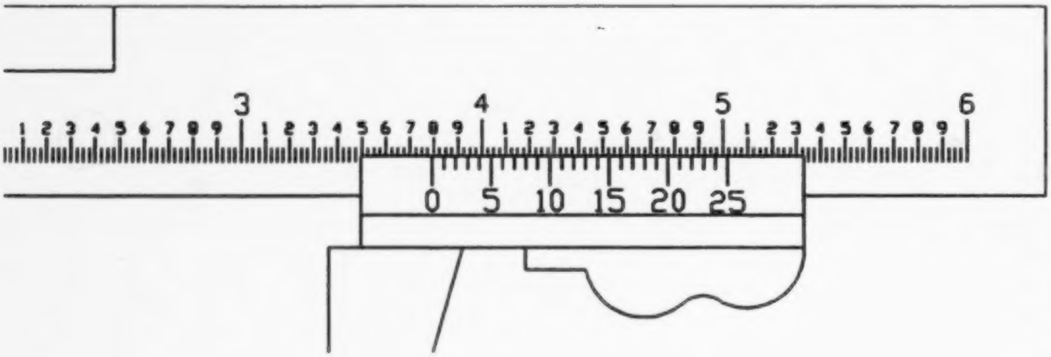
6
1 2 3 4 5 6 7 8 9 1 2 3 4 5 6 7 8 9 1 2 3 4 5 6 7 8 9 1 2 3 4 5 6 7 8 9
0
5
10
15
20
25

3. What is the reading on the vernier caliper below?
   - a. 4.575
   - b. 4.250
   - c. 4.570
   - d. 4.275


3
4
5
6
1 2 3 4 5 6 7 8 9
0 5 10 15 20 25

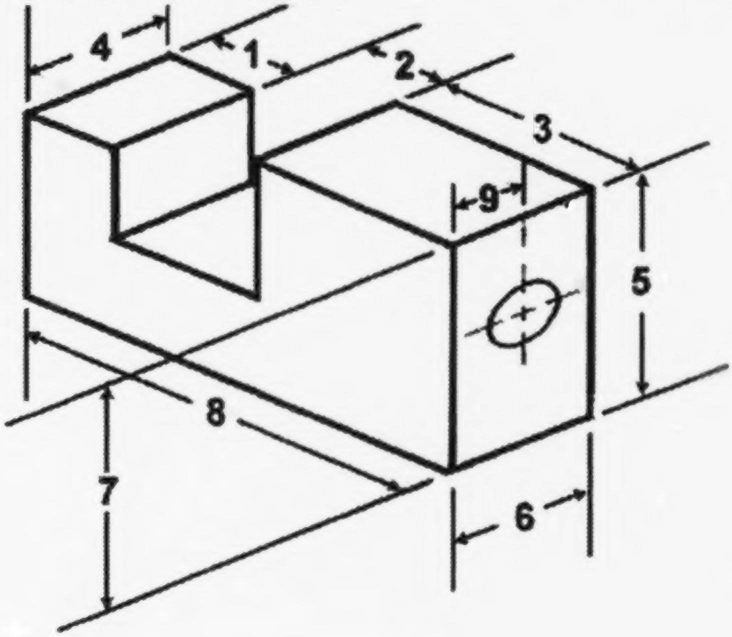
4. What is the reading on this vernier caliper?
   - a. 3.785
   - b. 3.800
   - c. 3.473
   - d. 3.793


3
4
5
6
1 2 3 4 5 6 7 8 9
0 5 10 15 20 25

Name____________________ Date____________

CNC-E3-LE2
Measure With Hand Held Instruments
Attachment 3: MASTER Laboratory Exercise No. 2

Using the measuring instruments provided for you and the measuring specimens, measure for the following dimensions and record your answers in the space provided. Be sure to provide metric and inch answers for each dimension. Turn this sheet in to your instructor for evaluation.



Specimen Number ______

Dimension	metric	inch	Dimension	metric	inch
1.	____	____	7.	____	____
2.	____	____	8.	____	____
3.	____	____	9.	____	____
4.	____	____	10.	____	____
5.	____	____	11.	____	____
6.	____	____			

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
   a. No loose clothing, including ties;
   b. Long hair properly stowed;
   c. No jewelry;
   d. Hard, closed-toe shoes;
   e. Eye protection (safety glasses); and,
   f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

CNC-E4-HO
Eliminate Measurement Variables
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:

- a. Discuss factors affecting accurate measurement (dirt, temperature, improper measuring tool calibration);
- b. Explain calibration requirements of various precision instruments;
- c. Illustrate measurement differences when taken with calibrated and non-calibrated instruments; and,
- d. Calibrate a micrometer type measuring tool.

Module Outline:

- I. Discuss Factors Affecting Accurate Measurement
  - A. Tool selection
  - B. Cleanliness
  - C. Temperature
  - D. Calibration
  - E. "Feel"
- II. Explain Calibration Requirements of Various Precision Instruments
  - A. Individual responsibility vs. company responsibility
  - B. Calibration standards
- III. Illustrate Measurement Differences When Taken With Calibrated and Non-Calibrated Instruments
- IV. Calibrate a Micrometer Type Measuring Tool
  - A. 5 steps adjusting an outside micrometer which needs adjustment
    1. Clean the measuring faces of the micrometer
    2. Close the measuring faces carefully against the standard by turning the ratchet stop or friction thimble
    3. Insert the C-spanner into the hole or slot provided in the sleeve
    4. Carefully turn the sleeve until the index line on the sleeve coincides with the zero line on the thimble
    5. Recheck the accuracy of the micrometer by opening and then closing the micrometer faces by turning the ratchet stop or friction thimble
  - B. Student practice of the above procedure

CNC-E4-LE
Eliminate Measurement Variables
Attachment 2: MASTER Laboratory Exercise

The student will perform the following:

1. Calibrate a micrometer by:
    a. Adjusting micrometer;
    b. Cleaning the measuring faces of the micrometer;
    c. Closing the measuring faces carefully against the standard by turning the ratchet stop or friction thimble;
    d. Inserting the C-spanner into the hole or slot provided in the sleeve;
    e. Carefully turning the sleeve until the index line on the sleeve coincides with the zero line on the thimble; and,
    f. Rechecking the accuracy of the micrometer by opening and then closing the micrometer faces by turning the ratchet stop or friction thimble.

Rules of Conduct

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3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
   a. No loose clothing, including ties;
   b. Long hair properly stowed;
   c. No jewelry;
   d. Hard, closed-toe shoes;
   e. Eye protection (safety glasses); and,
   f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

CNC-E5-HO
Measure/Inspect Using Surface Plate and Accessories
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:
- a. Describe care of surface plate;
- b. Use surface plate accessories correctly (sine bar, gage blocks, etc.);
- c. Check for part squareness;
- d. Check part dimensions for accuracy; and,
- e. Align workpieces using height gage and dial indicators.

Module Outline:

- I. Describe Types of Surface Plate and Surface Tables
    - A. Cast iron and semi-steel surface plates
    - B. Granite surface plate
- II. Discuss the Different Surface Plate Accessories and Their Use
    - A. Sine bar
    - B. Gage blocks
    - C. Vernier height gage
    - D. Precision height gage
    - E. Dial test indicator
    - F. Squares
    - G. Angle plate and clamps
    - H. 1,2,3 blocks
- III. Demonstrate Checking For Part Squareness
- IV. Demonstrate Checking Part Dimensions For Accuracy
- V. Demonstrate Aligning Workpieces Using Height Gage and Dial Indicators

Measure/Inspect Using Surface Plate and Accessories
Attachment 2: MASTER Laboratory Exercise

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1. Instructor will provide sample mechanical parts for students to:
   a. Demonstrate checking for part squareness;
   b. Demonstrate checking part dimensions for accuracy; and,
   c. Demonstrate aligning workpieces using height gage and dial indicators.

2. Students will practice:
   a. Checking for part squareness;
   b. Checking part dimensions for accuracy; and,
   c. Aligning workpieces using height gage and dial indicators.

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
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3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

CNC-E6-HO
Inspect Using Stationary Equipment
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Set up and use an Optical Comparator; and,

b. Set up and use a Coordinate Measuring Machine (CMM).

Module Outline:

I. Define the Term "Comparison Measurement"
  A. Describe the following comparison instruments:
    1. Dial indicator
    2. Mechanical comparator
    3. Optical comparator
    4. Mechanical-optical comparator
    5. Air gages
    6. Electronic comparator
  B. Demonstrate the setup and operation of the optical comparator
  C. Allow students to practice setup and operation of the optical comparator
II. Discuss the Advantages of Measuring with the Coordinate Measuring Machine (CMM)
  A. Demonstrate the setup and operation of the CMM
  B. Allow students to practice setup and operation of the CMM

CNC-E6-LE
Inspect Using Stationary Equipment
Attachment 2: MASTER Laboratory Exercise

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1. The instructor will:
    a. Demonstrate the setup and operation of the optical comparator; and,
    b. Demonstrate the setup and operation of the Coordinate Measuring Machine (CMM).

2. The students will:
    a. Practice the setup and operation of the optical comparator; and,
    b. Practice the setup and operation of the Coordinate Measuring Machine (CMM).

Rules of Conduct

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4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

CNC MACHINIST .... programs, edits, sets up, and operates CNC lathes, mills and grinders to perform machining operations necessary to produce workpieces to referenced engineering standards.

	Duties	← Tasks →												
A	**Practice Safety**	A-1 Follow safety manuals and all safety regulations/ requirements	A-2 Use protective equipment	A-3 Follow safe operating procedures for hand and machine tools	A-4 Maintain a clean and safe work environment	A-5 MSDS/ control chemical hazards								
B	**Apply Mathematical Concepts**	B-1 Perform basic arithmetic functions	B-2 Convert fractions/ decimals	B-3 Convert Metric/ English measurements	B-4 Perform basic algebraic operations	B-5 Use practical geometry	B-6 Understand basic trigonometry	B-7 Calculate speeds and feeds for machining	B-8 Use coordinate systems					
C	**Interpret Engineering Drawings and Control Documents**	C-1 Identify basic layout of drawings	C-2 Identify basic types of drawings	C-3 Review blueprint notes and dimensions	C-4 List the purpose of each type of drawing	C-5 Verify drawing elements	C-6 Practice Geometric Dimensioning and Tolerancing (GD&T)	C-7 Analyze bill of materials (BOM)	C-8 Describe the relationship of engineering drawings to planning	C-9 Understand and use quality systems	C-10 Verify standard requirements			
D	**Recognize Different Manufacturing Materials and Processes**	D-1 Identify materials with desired properties	D-2 Identify materials and processes to produce a part	D-3 Describe the heat treating process	D-4 Test metal samples for hardness	D-5 Understand welding operations								
E	**Measure/ Inspect**	E-1 Understand metrology terms	E-2 Select measurement tools	E-3 Measure with hand held instruments	E-4 Eliminate measurement variables	E-5 Measure/ inspect using surface plate and accessories	E-6 Inspect using stationary equipment							
F	**Perform Conventional Machining**	F-1 Prepare and plan for machining operations	F-2 Use hand tools	F-3 Operate power saws	F-4 Operate drill presses	F-5 Operate vertical milling machines	F-6 Operate horizontal milling machines	F-7 Operate metal cutting lathes	F-8 Operate grinding/ abrasive machines					
G	**Perform Advanced Machining**	G-1 Understand CNC basics	G-2 Program CNC machines	G-3 Operate CNC machining centers (mills)	G-4 Operate CNC turning centers (lathes)									
H	**Use Verification and Communication Systems**	H-1 Use personal computer	H-2 Use various operating systems	H-3 Use computer communications systems	H-4 Use verification systems	H-5 Use the Internet								
I	**Program Using CAM System**	I-1 Understand CAD/ CAM programs	I-2 Manipulate CAD functions	I-3 Process simple tool-path data	I-4 Create advanced surface models	I-5 Process complex tool-path functions								

CNC-F1-HO
Prepare and Plan for Machining Operations
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:
- a. Read and interpret blueprints;
- b. Understand machinability and chip formation;
- c. Use the *Machinery's Handbook* as a reference for machine applications;
- d. Describe the tools and toolholders will be needed for machining operations;
- e. Calculate speeds, feeds, and depth of cut for various machine operations;
- f. Use carbides and other tool materials;
- g. Assemble work holding (fixturing) components; and,
- h. Perform basic semi-precision and precision layout as necessary.

Module Outline:

- I. Plan for Machining Operation
  - A. Read and interpret blueprints
  - B. Understand machinability and chip formation
  - C. Use the *Machinery's Handbook* as a reference for machine applications
  - D. Answer the following questions
    - 1. What operations are necessary to produce the part? (qualify, rough, finish, grind, face, turn, thread, groove, etc.)
    - 2. What sequence of tools will be used?
    - 3. How will the part be fixtured? Fasteners should not interfere with machine moves. (Clamps, vise, chucks, collets, etc.)
    - 4. How many set-ups will be required?
    - 5. What is the accuracy required for machining dimensions?
- II. Prepare for Machining Operations
  - A. What type of tools and toolholders will be needed for roughing, finishing, etc.? Use carbides and other tool materials when available. Verify tool availability.
  - B. Calculate speeds, feeds, and depth of cut for various machine operations
  - C. Assemble work holding (fixturing) components
  - D. Perform basic semi-precision and precision layout as necessary
  - E. Load the part into the workholding (fixturing) device

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    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

CNC-F2-HO
Use Hand Tools
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Select and use hand tools;
b. Select and use hand files;
c. Correctly identify and use hand taps and dies as required;
d. Select and use hand reamers;
e. Use arbor and shop presses; and,
f. Perform off-hand grinding operations.

Module Outline:

I. Select and Use Hand Tools
  A. Bench vise
  B. Clamps
  C. Pliers
  D. Hammers
  E. Wrenches
  F. Screwdrivers
  G. Chisels and punches
  H. Hacksaws
II. Select and Use Hand Files
  A. Types of files
    1. Mill file
    2. Long angle (lathe) file
    3. Bastard files
  B. Shapes of files
    1. Pillar files
    2. Square files
    3. Warding files
    4. Knife files
    5. Three-square files
    6. Half-found files
    7. Round files
  C. Specialty files
    1. Swiss pattern files
    2. Die sinker's rifflers
    3. Curved tooth files
    4. Thread files
    5. Rotary files and burrs

6. Scrapers
D. Care and use of files
1. Proper care of files
2. Proper use of files
a. Cross filing
b. Draw filing
E. Student filing practice
III. Correctly Identify and Use Hand Taps and Dies as Required
A. Identification of taps
1. Identifying marks on inch taps (example: ½-13-UNC)
a. Nominal size = ½"
b. Threads per inch = 13
c. Standardized thread series = Unified National Coarse
2. Identifying marks on metric taps (example: M4 X 0.7)
a. M = metric thread
b. Nominal diameter of the thread = 4mm
c. Pitch of the thread = 0.7mm
3. Standard taps
a. Taper (starting) taps
b. Plug taps
c. Taper taps
4. Special taps
a. Pipe taps
b. Pulley taps
c. Acme thread taps
B. Care and use of taps
1. Proper care of hand taps
2. Determining tap drill size
a. Tap drill size chart
b. Tap drill size formula for inch taps
Tap Drill Size = Major Diameter of the Tap minus 1 divided by the number of threads per inch
c. Tap drill size formula for metric taps
Tap Drill Size = major diameter (mm) minus the pitch (mm)
3. Demonstrate proper use of hand taps
4. Broken tap removal
a. Tap extractor
b. Acid
c. Electrical discharge
C. Identification and use of threading dies
1. Solid die - for chasing or recutting damaged threads
2. Adjustable split die - for cutting threads over or under the standard depth of thread

        - 3. Adjustable screw plate die - most efficient type of adjustable die for cutting external threads
    - D. Student tap and die practice
- IV. Select and Use Hand Reamers
    - A. Types of hand reamers
        - 1. Straight fluted reamers
        - 2. Spiral fluted reamers
        - 3. Expansion reamers
        - 4. Adjustable hand reamers
        - 5. Taper reamers
    - B. Care and Use of Hand Reamers
        - 1. Proper care of hand reamers
        - 2. Proper use of hand reamers
    - C. Student hand reaming practice
- V. Perform Finishing Processes
    - A. Broaching
    - B. Lapping
    - C. Polishing
- VI. Use Arbor and Shop Presses
    - A. To install bushings/bearings
    - B. To press shafts in and out of gears and sprockets
    - C. To seat mandrels
    - D. To broach keyways
    - E. To bend and straighten
- VII. Perform Off-Hand Grinding Operations
    - A. Setting up the grinder (demonstration)
        - 1. Grinding wheel selection
        - 2. Grinding wheel "ring test"
        - 3. Mounting the grinding wheel
        - 4. Tool rest adjustment
        - 5. Dressing the grinding wheel
    - B. Perform off-hand grinding exercises (demonstration)
        - 1. Sharpen a flat blade screwdriver
        - 2. Sharpen a cold chisel
        - 3. Grind/Sharpen a high speed cutting bit
    - C. Student practice of grinding exercises

CNC-F2-LE
Use Hand Tools
Attachment 2: **MASTER** Laboratory Exercise

For this exercise, you will make a drill/hole gage.

Necessary Equipment:

- 1/8" x 2" x 8" steel bar (cold finish)
- 3/4" radius gage
- File, Double cut
- File, single cut
- Hacksaw
- Layout tools
- Steel Rule for straight edge
- Vise

I. Layout
   - A. Scribe the cutting lines.
   - B. Scribe the hole centers.
   - C. Center punch the hole centers.

II. Cutting
   - A. Leave a 1/32" lip on each cut. This lip will be filed off to finish the tool.
   - B. Make sure that the workpiece is firmly in the vise and that the clearance is sufficient to allow cutting.
   - B. Cut the 30° angle. Make certain that you do not cut into the body of your tool.
   - C. Cut the interior edge. Make sure that you do not cut into the lip rule of your tool.

III. Filing
   - A. Straight surfaces
     1. Using a single cut file, draw file all straight edges.
     2. Check the smoothness with the steel rule by holding the steel rule along one edge and looking toward a light.
     3. Continue filing the edge until almost no light is visible between the rule and the gage.
   - B. 3/4" radius
     1. Clamp the workpiece securely in the vise.
     2. Using the double cut file, file off the corner, leaving a 1/32" lip for finishing.
     3. Using the single cut file, round the corner by filing forward and downward.
     4. Frequently check the finish with the 3/4" radius gage.

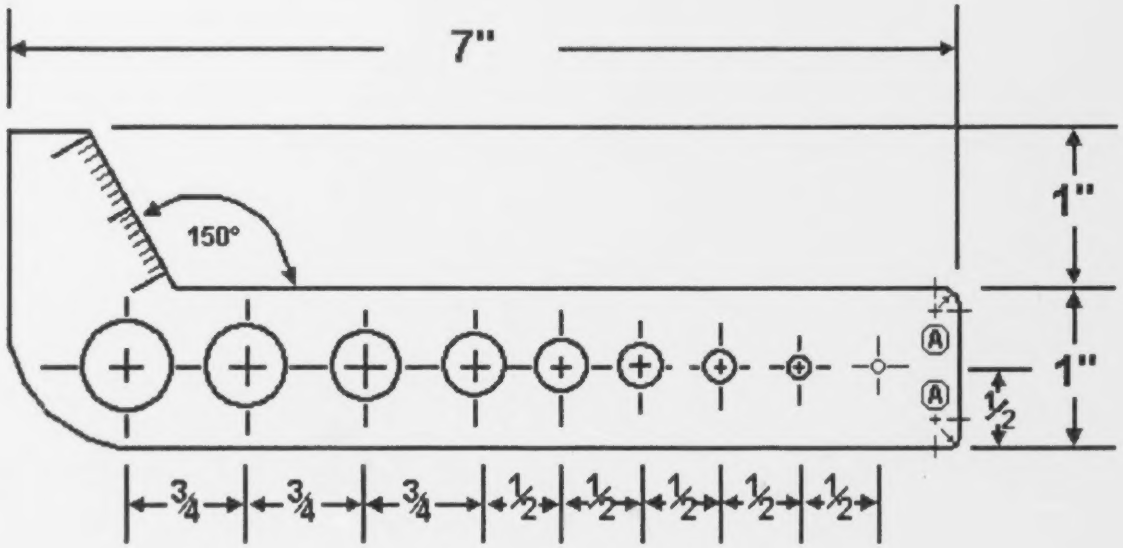
IV. Scribing the lip gage

A. The 30° edge should be marked at 1/16" intervals.
B. Ensure that all lines are parallel.
C. Scribe them into the edge by the method recommended by your instructor.

All Holes Bored Through
Hole Sites:
Left-to-Right

9/16"
1/2"
7/16"
3/8"
5/16"
1/4"
3/16"
1/8"
1/16"

Ⓐ 1/4" radius round



CNC-F2-LA
Use Hand Tools
Attachment 3: **MASTER** Laboratory Aid

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

CNC-F3-HO
Operate Power Saws
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Use reciprocating and horizontal band cutoff machines;
b. Operate abrasive and cold saws; and,
c. Setup and use the vertical band saw.

Module Outline:

- I. Cutoff Type Metal Saws
  - A. Four types of cutoff saws
    - 1. Power hacksaw - reciprocating type which cuts only on the forward stroke. It is not generally considered to be one of the most efficient cutoff machines in the machine shop.
    - 2. Horizontal bandsaw - uses a flexible, continuous blade which cuts continuously. They are available in a wide variety of types and sizes and are popular because of their high production and versatility.
    - 3. Abrasive cutoff saw - cuts metal with a thin abrasive blade which revolves at a high speed. One of it's strengths is that it can easily cut hardened metal.
    - 4. Friction saw - uses a saw band (usually without teeth) which is run at a very high speed (10,000 to 25,000 sfm) and burns or melts it way through metal. Ideal for cutting thin sections of structural and honeycombed parts of machine or stainless steel.
  - B. Types of saw blades
    - 1. Material - high-speed tungsten and high-speed molybdenum steel is used for saw blades. Power hacksaws have blades which are hardened throughout while flexible blades have only the saw teeth hardened.
    - 2. Pitch - pitch is the number of teeth per inch. When cutting thick materials choose a saw blade with a course pitch, such as 4-6 to allow for proper chip clearance and maximum bite. When cutting thin materials choose a saw blade with a fine pitch, such as 12-14. 10 pitch is considered to be a good general purpose blade. (*Rule:* Always use a blade which will allow at least 2 teeth to be in contact with the work at all times to avoid tooth breakage.)
  - C. Blade removal and installation
    - 1. Always turn the electrical power off

    2. Use a brush to clean the areas (guides) through which the blade must pass
    3. Carefully release any blade tensioning device and remove the blade
    4. Select the correct blade for the cutting job at hand
    5. Install the blade with the teeth facing in the proper cutting direction
    6. Tighten the blade tensioning device checking that the blade is properly aligned and tensioned
    7. Quickly start and stop the saw to verify proper operation
    8. For saws which have adjustable speeds, set the proper cutting speed for the metal to be cut
- D. Operation
    1. Check vise mounting for tightness and squareness to the cutting blade
    2. Place material in the vise (support long pieces with a floor stand)
    3. Lower the saw blade until it is close to the work
    4. Adjust any blade guides until they just clear the sides of the material to be cut
    5. Measure the part to be cut, allowing 1/16" or more for saw run-out
    6. Tighten the vise, check length measurement and turn the saw on
- E. Sawing hints
    1. Never attempt to mount, measure, or remove work unless the saw is stopped
    2. Guard long material at both ends to prevent anyone from coming in contact with it
    3. Use cutting fluid when possible to help prolong the life of the saw blade
    4. When several pieces of the same length are to be cut, set the stop gage to the desired length
    5. If the blade dulls or breaks, re-start the cut in a new place
- F. Student practice
    1. Students should select proper pitch blade for a cutting application
    2. Students should practice removal/installation of a saw blade
    3. Students should use the saw to cut a piece of metal to length
    4. Students should operate abrasive and cold saws if available

II. The Vertical Contour Bandsaw

- A. Description of the contour bandsaw parts and accessories
    1. Base
    2. Column
    3. Head

- B. Bandsaw Applications
  - 1. Notching
  - 2. Slotting
  - 3. Splitting
  - 4. Radius cutting
  - 5. Angular cutting
  - 6. Three-dimensional shaping
- C. Blade Variables/Types (the text has excellent illustrations for each of these)
  - 1. Tooth forms -
    - a. Precision or regular
    - b. Claw or hook tooth
    - c. Buttress or skip tooth
  - 2. Pitch - the number of teeth per inch (see above discussion at I,B,2)
  - 3. Set - amount of side to side offset of the teeth for clearance
    - a. Wave
    - b. Straight
    - c. Raker
  - 4. Width - the distance from the tip of the teeth to the back of the blade
    - a. For making straight cuts, select a wide blade
    - b. For cutting small radii, select a narrow blade
    - c. For general cutting, select the widest blade which can cut the smallest radius on the workpiece
  - 5. Gage - the thickness of the saw blade
- D. Bandsaw operation
  - 1. Instructor demonstration of the following
    - a. Blade removal/assembly
      - 1. Unfolding/folding saw blades
      - 2. Measuring and cutting stock saw blade material
      - 3. Welding a saw blade using the band welder
    - b. Cutting speed adjustment
    - c. Saw guide adjustments
    - d. Careful operation of the bandsaw
  - 2. Student practice of the following steps
    - a. Blade removal/assembly
      - 1. Unfolding/folding saw blades
      - 2. Measuring and cutting stock saw blade material
      - 3. Welding a saw blade using the band welder
    - b. Cutting speed adjustment
    - c. Saw guide adjustments
    - d. Careful operation of the bandsaw

III. Cleanup and Review of Main Lesson Points

CNC-F3-LE1
Operate Power Saws
Attachment 2: **MASTER** Laboratory Exercise No. 1

Laboratory Exercise No. 1:

1. Instructor will demonstrate how to setup and operate a band saw to a designated tolerance without endangering personnel or equipment by:
   - A. Selecting proper blade;
   - B. Installing and properly adjusting the blade;
   - C. Adjusting the blade guides and guard;
   - D. Adjusting the coolant flow if or as appropriate;
   - E. Adjusting feed control (if applicable);
   - F. Properly securing the work and making a cut to specified tolerances; and,
   - G. Shutting down the machine and cleaning up work area.

2. Student will demonstrate how to setup and operate a band saw to a designated tolerance without endangering personnel or equipment by:
   - A. Selecting proper blade;
   - B. Installing and properly adjusting the blade;
   - C. Adjusting the blade guides and guard;
   - D. Adjusting the coolant flow if or as appropriate;
   - E. Adjusting feed control (if applicable);
   - F. Properly securing the work and making a cut to specified tolerances; and,
   - G. Shutting down the machine and cleaning up work area.

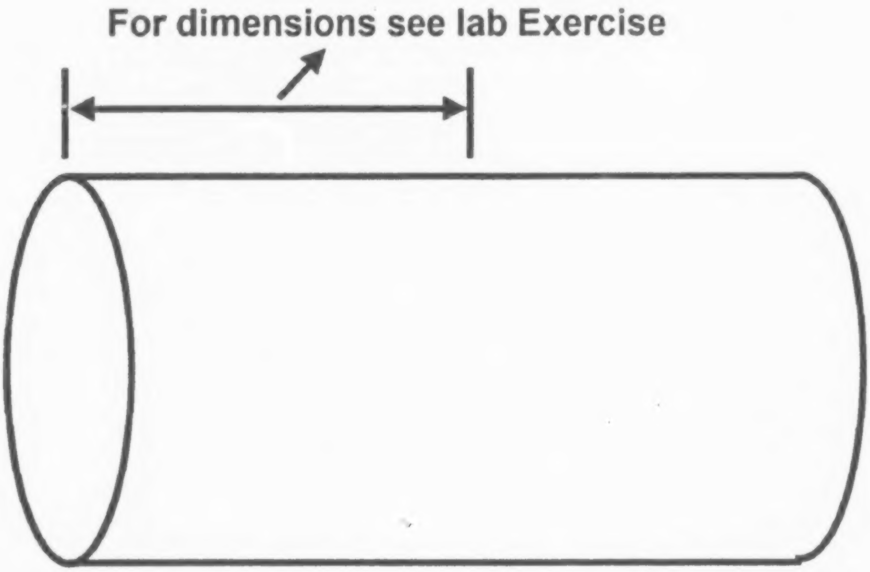
3. Instructor will grade student's performance.

Laboratory Exercise No. 2:

Using each of the saws discussed in the module, the student will cut five workpieces, in different metals or grades of steel. The required accuracy is +/-1/16".

The following five lengths should be cut by each student:

1. 4"
2. 2.5"
3. 40 mm
4. 5 1/8"
5. 50 mm



Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

CNC-F4-HO
Operate Drill Presses
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Describe the different types of drill presses found in the machine shop;
b. Select and use the standard drilling machine accessories;
c. Select and use standard drilling tools;
d. Sharpen a drill bit using a bench or pedestal grinder; and,
e. Layout, setup and perform these drilling operations: drilling, tapping, countersinking, counterboring, reaming.

Module Outline:

I. Describe the Different Types of Drill Presses Found in the Machine Shop
  A. Sensitive drill press
  B. Upright drill press
  C. Radial drill press
  D. CNC drilling machines
II. Select and Use the Standard Drilling Machine Accessories
  A. Tool-holding devices
    1. Drill chucks
    2. Drill sockets, sleeves and drifts
  B. Work-holding devices
    1. Drill vise
    2. V-blocks
    3. Angle plate
    4. Clamps and straps
III. Select and Use Standard Drilling Tools
  A. Twist drills
    1. Shank
    2. Body
    3. Points
    4. Sizes
      a. Fractional size drills
      b. Number size drills
      c. Letter size drills
      d. Metric drills
    5. Special types of drills
      a. Straight-fluted
      b. Spade drills
      c. Deep hole drills

d. Core drills
6. Cutting fluids
a. Drilling
b. Tapping
B. Sharpen a drill bit using a bench or pedestal grinder
1. Review grinder safety
2. Discuss the following drill point characteristics
a. Chisel edge
b. Lip clearance
c. Lip length
d. Web thinning
3. Demonstrate this for the students
4. Student practice
IV. Layout, Setup and Perform These Drilling Operations:
A. Drilling
1. Speed (rpm) - discuss the formula.....CS X 4 ÷ diam. = RPM
2. Feed (inch per revolution) - roughing and finishing
B. Countersinking
C. Counterboring
D. Reaming
1. Discuss reaming allowance
2. Speed is normally twice that used for drilling
3. Feed is normally ½ that used for drilling
E. Tapping
1. Discuss tap drill size
2. Discuss special taps for machine tapping

CNC-F4-LE1
Operate Drill Presses
Attachment 2: MASTER Laboratory Exercise No. 1

Laboratory Exercise No. 1:

Each student will be assigned two workpieces, made of either two different metals or two greatly different grades of steel.

1. For the first piece, the student will drill, ream, *counterbore*, and tap the following holes:
   - A. 3/16"
   - B. 1/2"
   - C. 5/8"
   - D. 4mm
   - E. 12mm

2. For the second piece, the student will drill, ream, *countersink*, and tap the following holes:
   - A. 3/16"
   - B. 1/2"
   - C. 5/8"
   - D. 4mm
   - E. 12mm

Laboratory Exercise No. 2:

You will now complete your Drill/Hole Gage.

Necessary Equipment:

- #2 Center Drill
- Countersinks of appropriate sizes
- Drill Bits: 9/16", 1/2", 7/16", 3/8", 5/16", 1/4", 3/16", 1/8", 1/16"
- Set of Parallels
- Vise

I. Test the drill bits which you will use. Sharpen them as necessary.

II. Set up the gage and the parallels in the vise so that the 3/4" bit will clear through the gage.

III. With the machine OFF, emplace the center drill. The drill should be centered for the 3/4" hole.

IV. *Without moving the workpiece,* tighten the vise.

V. Drilling

  A. Set the machine to the correct speed for the drill size you are using.

  B. Spot drill all the holes *except* the 1/16" hole. (Spot drilling this hole may cause it to be over size in the finished tool).

  C. Change to the 1/16" bit and drill the hole.

  D. Change to the 1/8" bit and drill that hole. Using the 1/8" bit, pilot drill all larger holes.

  E. Drill the other holes.

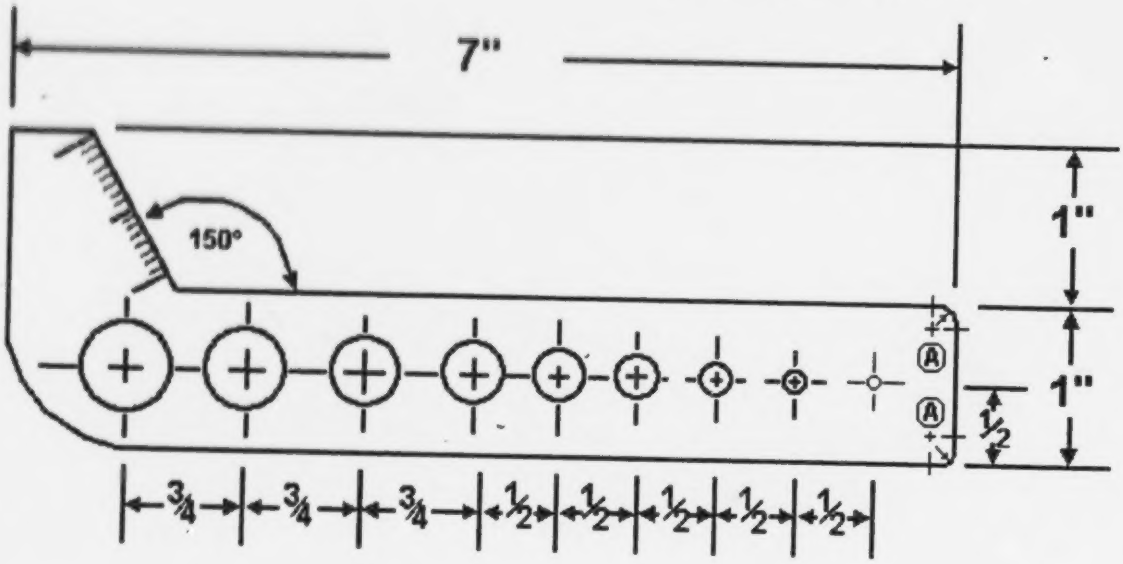
  F. Be sure to check the machine speed for each drill size. Adjust the machine speed as necessary.

VI. Countersink each side of each hole. A minimal chamfer is all that is required.

All Holes Bored Through
Hole Sites:
Left-to-Right

9/16"	1/4"
1/2"	3/16"
7/16"	1/8"
3/8"	1/16"
5/16"	

Ⓐ 1/4" radius round


7"
150°
1"
1"
½
Ⓐ
Ⓐ
¾
¾
¾
½
½
½
½
½

Rules of Conduct

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4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

CNC-F5-HO
Operate Vertical Milling Machines
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Demonstrate the use of all controls on the vertical milling machine;
b. Align the vertical milling machine head;
c. Select, align, and use workholding devices;
d. Select milling tool holders;
e. Select milling cutters;
f. Perform all standard vertical milling operations;
g. Bore a hole using the offset boring head;
h. Machine angles using sine bar and gage blocks;
i Machine keyways; and,
j. Setup and machine dovetails.

Module Outline:

I. Identify Parts and Use All Controls on the Vertical Milling Machine
   A. Base
   B. Column
   C. Knee
   D. Saddle
   E. Table
   F. Ram
   G. Toolhead
   H. Motor
   I. Turret Clamps
   J. Quill, Quill Jack, and Spindle
   K. Controls
      1. Forward/Reverse Motor Switch
      2. Spindle Brake
      3. Power Feed Change Lever
      4. Quill Feed Handwheel
      5. Feed Control Lever
      6. Quill Feed Hand Lever
      7. Feed Reverse Knob
      8. High/Low Speed Change Lever
      9. Variable Speed Control Wheel
      10. Table Reverse Crank
      11. Vertical Traverse Crank
      12. Cross Traverse Crank

        - 13. Table Power Feed
    - L. Locks and Gib Adjusting Screws
- II. Setup Milling Machine
    - A. Square the Toolhead to Table and Saddle Axes
    - B. Select, Align, and Use Workholding Devices
        - 1. Direct Table Mounting
        - 2. Mill Vises
        - 3. Work Edge and Hole Centerline Locating
    - C. Select Milling Tool Holders
        - 1. Solid Collet
        - 2. Split Collet
        - 3. Quick-Change Systems
        - 4. Arbor
    - D. Select Milling Cutters
        - 1. High-Speed Steel Helical End Mills
        - 2. HSS Straight-Flute End Mills
        - 3. Carbide EMs
        - 4. Roughing and Tapering EMs
        - 5. Geometry-Forming EMs
        - 6. Dovetail EMs
        - 7. T-Slot EMs
        - 8. Woodruff Key EMs
        - 9. Shell End Mills
        - 10. Flycutters
- VI. Perform All Standard Vertical Milling Operations
    - A. Basic Operations and Terms
        - 1. Climb Milling vs Conventional Milling
        - 2. Factors Affecting Cutting Performance
        - 3. Cutting Fluids
            - a. Purpose and Use
            - b. Selection
            - c. Safety
    - D. Milling Cavities
    - E. Angle Milling
    - F. Drilling
- VII. Bore a Hole Using the Offset Boring Head
    - A. Identify Parts of Boring Head
    - B. Workpiece Setup
    - C. Tool Selection
    - D. Use the Offset Boring Head
- VIII. Machine Angles Using Sine Bar and Gage Blocks
    - A. Identify Parts
        - 1. Sine Bar
        - 2. Sine Plate
        - 3. Use and Care of Gage Blocks

IX. **Machine Keyways**
X. **Setup and Machine Dovetails and T-Slots**

CNC-F5-LE
Operate Vertical Milling Machines
Attachment 2: **MASTER** Laboratory Exercise

I. **The student should align the vertical milling machine head.**

II. **The student should mill the following forms:**
   - A. **A keyseat in a shaft;**
   - B. **A set of short (no more than 18") dovetail joints;**
   - C. **A cavity in a block; and,**
   - D. **A T-slot in a block 6" long; the T-slot must be parallel to the long side of the block.**

III. Evaluation criteria:
   - A. **The chosen key must fit properly in the keyseat;**
   - B. **The dovetailed workpieces must mate properly;**
   - C. **The cavity in the block must be within the tolerances established by the instructor; and,**
   - D. **The T-slot must accept and freely pass the selected commercial T-nut.**

Rules of Conduct

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4. Dress appropriately; at the absolute minimum, you must have:
   a. No loose clothing, including ties;
   b. Long hair properly stowed;
   c. No jewelry;
   d. Hard, closed-toe shoes;
   e. Eye protection (safety glasses); and,
   f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

CNC-F6-HO
Operate Horizontal Milling Machines
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

- a. Discuss the difference in plain and universal horizontal milling machines;
- b. Discuss the types of spindles, arbors and adaptors used on the horizontal milling machine;
- c. List several common work holding methods;
- d. Use plain milling cutters;
- e. Use side milling cutters; and,
- f. Use face milling cutters.

Module Outline:

- I. Discuss the Difference in Plain and Universal Horizontal Milling Machines
  - A. Determine Machine Size
  - B. Identify Parts & Controls
    - 1. Base and Column
    - 2. Knee
    - 3. Saddle
    - 4. Table
    - 5. Spindle
    - 6. Overarm and Arbor Support
    - 7. Controls
      - a. Manual movement controls
      - b. Feed rate selector and feed engage
      - c. Rapid traverse
      - d. Spindle controls
      - e. Locks
    - 8. Swivel housing on saddle of Universal Milling Machine
- II. Discuss the Types of Spindles, Arbors, and Adaptors Used on the Horizontal Milling Machine
  - A. Mill Spindle Tapers
  - B. Arbors
    - 1. Style A
    - 2. Style B
    - 3. Style C
    - 4. Spacing Collars
    - 5. Bearing Collars
    - 6. Support Bearings

- C. Adapters
- D. Collets
- E. Quick-Change Systems

III. List Several Common Work Holding Methods
- A. Direct Table Mounts
  - 1. Clamp supports
  - 2. Screw jacks
- B. Mill Vises
- C. Miscellaneous Holders
  - 1. Rotary table
  - 2. Dividing head
  - 3. V-Blocks
  - 4. Specially made milling fixtures

IV. Use Plain Milling Cutters
- A. Roughing
- B. Squaring
- C. Milling Endpieces

V. Use Side Milling Cutters
- A. Setup
- B. Positioning the Cutter
- C. Making the Cut
  - 1. Keyseats
  - 2. Straddle and Gang Milling
- D. Helical Side Milling Cutters
  - 1. Uses
  - 2. Handedness

VI. Use Face Milling Cutters
- A. Composition and Inserts
- B. Uses
- C. Lead Angles and Rake Angles
- D. Wiper Flats

CNC-F6-LE
Operate Horizontal Milling Machines
Attachment 2: MASTER Laboratory Exercise

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1. The instructor will demonstrate:
    a. How to use plain milling cutters;
    b. How to use side milling cutters;
    c. How to use face milling cutters;
    d. How to recognize and utilize various spindles, arbors, and adaptors; and,
    e. How to set up workpieces appropriately.

2. Students will:
    a. Use plain milling cutters;
    b. Use side milling cutters;
    c. Use face milling cutters;
    d. Recognize and utilize various spindles, arbors, and adaptors; and,
    e. Set up workpieces appropriately.

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

CNC-F7-HO
Operate Metal Cutting Lathes
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Identify major component parts of an engine lathe;
b. Properly set up and use lathe accessories required for basic lathe operation;
c. Determine correct speed and feed for a given metal;
d. Identify safety concerns relative to lathe operation;
e. Demonstrate set up and use of lathe centers;
f. Identify and use different types of lathe cutting tools;
g. Face, cut and turn stock to a specified tolerance;
h. Demonstrate method of drilling, boring and reaming a hole to obtain specified tolerance; and,
i Demonstrate setup and correct procedures to machine sixty-degree internal and external threads.

Module Outline:

I. Discuss the Importance of the Lathe to the Machinist. Provide Classroom Handouts and Laboratory Worksheets to the Students.
II. Identify and Discuss Component Parts of the Engine Lathe
III. Discuss Lathe Safety
IV. Identify, Set Up, and Demonstrate Use of Lathe Accessories
    A. Cutting Fluids
    B. Follower and Steady Rest
    C. Compound Rest
    D. Mandrel
V. Discuss and Demonstrate How to Select the Correct Speed and Feed for Various Metals
    A. Steel
    B. Aluminum
    C. Brass
VI. Discuss and Demonstrate the Use of Lathe Centers
    A. Mounting
    B. Removing
    C. Aligning
VII. Discuss and Demonstrate Use of Cutting Tools
    A. Grinding a high speed toolbit
    B. Re-conditioning point of toolbits
    C. Types of cutting tools

VIII. *Discuss and Demonstrate Turning Between Centers*
  - A. Why face out?
  - B. Center drill
  - C. Tailstock center
  - D. The steady rest
  - E. Using chucks

IX. Discuss and Demonstrate Methods of Drilling, Boring, and Reaming Using the Lathe

X. Discuss Threads, Threading, and Thread Applications

XI. Student Practice

CNC-F7-LE
Operate Metal Cutting Lathes
Attachment 2: MASTER Laboratory Exercise

I. **The instructor will discuss and review the working drawings.**

II. **Students will practice safe work habits at all times.**

III. **Students will review the work prints at their work stations. (Be sure you understand *all aspects* of the working drawings before beginning the exercise.)**

IV. Specific Procedures for This Exercise
  A. General Shop Rules
    1. **Immediately put absorbent on all oil spills.**
    2. **Thoroughly clean the machine and the area around it when you are finished working at that station.**
    3. **Return all assigned tools to their proper places.**
  B. General Lathe Rules
    1. **Never attempt to stop a turning chuck.**
    2. **Never try to measure moving parts. Wait until they stop.**
    3. **The chuck should always turn *toward* you when it is in the FORWARD position.**
    4. **The tool steel should not stick out more than one-half inch from the toolholder.**

V. Fabrication of the Ball-Peen Hammer—Handle Form
  A. **Cut off at least 9 5/8 inches of 1 inch diameter CRS (cutting speed 100); wipe it clean and deburr it on the pedestal grinder using the coarse wheel.**
  B. **Check the following before starting the lathe.**
    1. **The spindle should be free.**
    2. **The carriage should be free.**
    3. **The cross feed should be free.**
    4. **The chuck wrench must be removed from the chuck.**
  C. **Face the stock to a length of 9 ½ inches.**
  D. **Center drill each end.**
  E. **Put the chuck on 2 inches of the stock and support the workpiece with the tailstock and the live center.**
  F. **Mark 6 inches from the end of the workpiece with the turning tool.**
  G. **Turn this 6 inches down to 0.800 inch.**
    1. **Touch the rotating workpiece with the tool and set the crossfeed dial to zero (0).**

  2. Take four cuts of 0.050 at a feed of 0.004.
  3. On the fourth cut, stop the feed after 3/8 inch and check for the proper diameter. Adjust as necessary.

H. Mark 5/8 inch from the end of the workpiece.
I. Turn this 5/8 inch down to 0.550.
J. File all edges using the file handle in the left hand.
K. File a straight flat along the turned surface in line with the #1 chuck jaw.
L. Unchuck the workpiece. *Remove the chuck wrench.*
M. Remove the workpiece and place 2 inches of the **turned** end into the chuck, placing the file flat under the #1 chuck jaw. *Remove the chuck wrench.*
N. Adjust the tailstock pressure so that the live center turns with the workpiece.
O. Mark 4 5/8 inches from the end and turn to 0.700 OD ± 0.005.
P. Mark 4 3/16 inches from the end and turn to 0.600 OD ± 0.005.
Q. Mark 3 3/8 inches from the end and turn to 0.425 OD ± 0.005.
R. Set the lathe to the proper feed and speed for finishing and finish the three ODs from O, P, & Q to the print dimensions.
S. Break all sharp edges with a file.
T. Reverse the work. Chuck on the 0.375 OD. *Remove the chuck wrench.* Protect the finished ODs with an appropriate buffer.
U. Finish turning the handle to the print dimensions.

VI. Fabrication of the Ball-Peen Hammer—Threads and the Head

A. Cut off at least 4 1/8 inches of 1 inch diameter 4140, painted red (cutting speed 60). Clean and deburr as before.
B. Face one end.
C. Mark 5/8 inch from the end and turn to 0.500 + 0.000 -0.010.
D. File a flat for the #1 chuck jaw, reverse the work and repeat B and C for the other end of the workpiece.
E. Get the parting tool for the respective machine.
  1. Check the parting tool for sharpness.
  2. Mount the parting tool in the tool post.
  3. Make sure that the parting tool is square to the workpiece and on center.
  4. Feed slowly, using both hands, at 100 RPM.

F. Cut a neck for the threads to run on at each end of the head and on one end of the handle.
  1. Touch the parting tool to the workpiece and zero the cross slide.
  2. Feed in the double depth of the thread plus 0.010.

G. Thread both ends of the head to ½-20-NF. Test the threads with a test nut. *Do not proceed to H without instructor approval.*
H. Thread one end of the handle to ½-20-NF.

- I. Either of two common methods of threading may be used. Check with the instructor before proceeding.
  - 1. Die and Pad
    - a. Fix the handle on the large end.
    - b. Using the die and the flat crotch pad, thread the small end of the handle to 3/8-24-NF.
  - 2. Threading Tool—thread to 3/8-24-NF.
- J. Chuck onto the practice threads of the head and support the workpiece with the tailstock and live center.
- K. Center drill the end of the head.
- L. Mark 1 7/8 inches from the shoulder and turn to 0.875 ± 0.003. Make sure that the top tolerance is used to allow for filing and polishing.
- M. Mark the #1 jaw, reverse the workpiece and center drill the other end.
- N. From the 0.875 OD, turn the workpiece down to 0.750 ± 0.003.
- O. Using the threading tool, mark the workpiece
  - 1. 13/16 inch *in from* the 0.875 OD.
  - 2. 3/8 inch in from the first mark.
  - 3. 5/8 inch in from the second mark.
  - 4. 3/8 inch in from the third mark.
- P. Under cut the 3/8 inch spaces to 9/16 inch OD ± 1/64. Use a round nose tool, set the RPM to 100, and feed by hand. Make the last cut slowly to leave the cut smooth.
- Q. Turn off the practice threads. Protect the finish in the chuck with an appropriate buffer.
- R. Crown face the head end and free-hand form the ball peen.
- S. Check all dimensions against the drawing for accuracy.

VII. Fabrication of the Ball-Peen Hammer — Knurling

- A. Chuck the handle at the 0.550 diameter (with proper buffers) and support the 0.500 diameter end with a well-lubricated dead center.
- B. Carefully mark where the knurl will be made.
- C. Set a medium knurling tool square to the workpiece and on center.
- D. Set the lathe to the proper feed and speed.
- E. Knurl the handle, using plenty of lubricants. Be sure that the pattern is correct *before* knurling the whole handle.
- F. Knurl the 1/4 inch cap screw. If a correct pattern is not obtained, knurl the entire handle grip and turn off the poorly-executed end.

VIII. Fabrication of the Ball-Peen Hammer — Completing the Handle

- A. Chuck on the knurl (buffer correctly).
- B. *While maintaining the tolerances,* file and polish each diameter of the handle separately.
- C. Clean the lathe especially well after polishing.

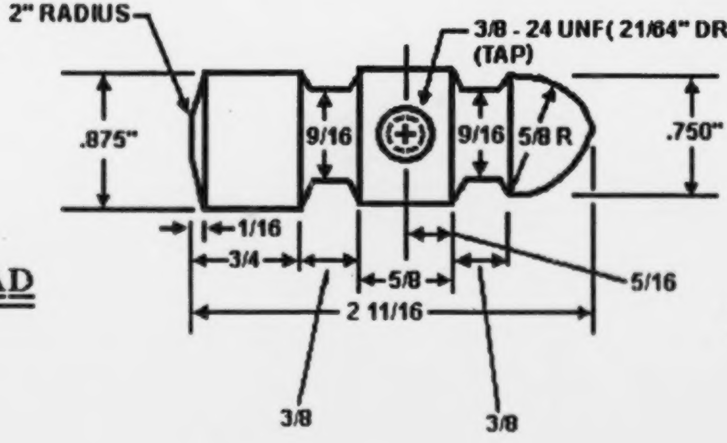
D. Move to the work bench. Place the handle in a vise (buffer the knurl) and saw off the end for the screw with a hacksaw.
E. Face the handle to length and drill and tap the storage hole as required.
F. Clean out the hole and install the screw. (A paper gasket may help prevent over-tightening.)
G. Face the screw to length and break the sharp edge. The handle is now complete.

IX. Fabrication of the Ball-Peen Hammer — Completing the Head
  A. Lay out, center punch, and drill the head to the proper depth. Use the drill jig designed for this operation.
  B. Tap the bore using a plug and bottom tap. Be sure the taps are started straight.
  C. Polish the hammer head and clean the work area.
  D. Heat the face of the hammer and the ball peen to cherry red; quench them in oil. Re-polish the head.
  E. Heat the face of the hammer and the ball peen to straw color; quench them in oil. Re-polish the head.

X. Turn in the hammer and blueprints to the instructor for evaluation. You will know how well you have done by whether the hammer parts all actually fit together well and whether they are within tolerances.

XI. Once you have obtained the instructor's approval, you are ready to begin construction of the gravity-fed center punch. For that exercise, you will **not** be given linear instructions. You must use your own judgement on how and when to do what, following the blueprints. Remember to stay within tolerances, to keep your work area clean, and keep your chuck key in your hand or in your tool kit *at all times and in all circumstances*. Good Luck!

HEAD


2" RADIUS
3/8 - 24 UNF(21/64" DRILL, 1/2" DEEP)
(TAP)
.875"
9/16
9/16
5/8 R
.750"
1/16
3/4
5/8
5/16
2 11/16
3/8
3/8

HAMMER GRADE: ____________

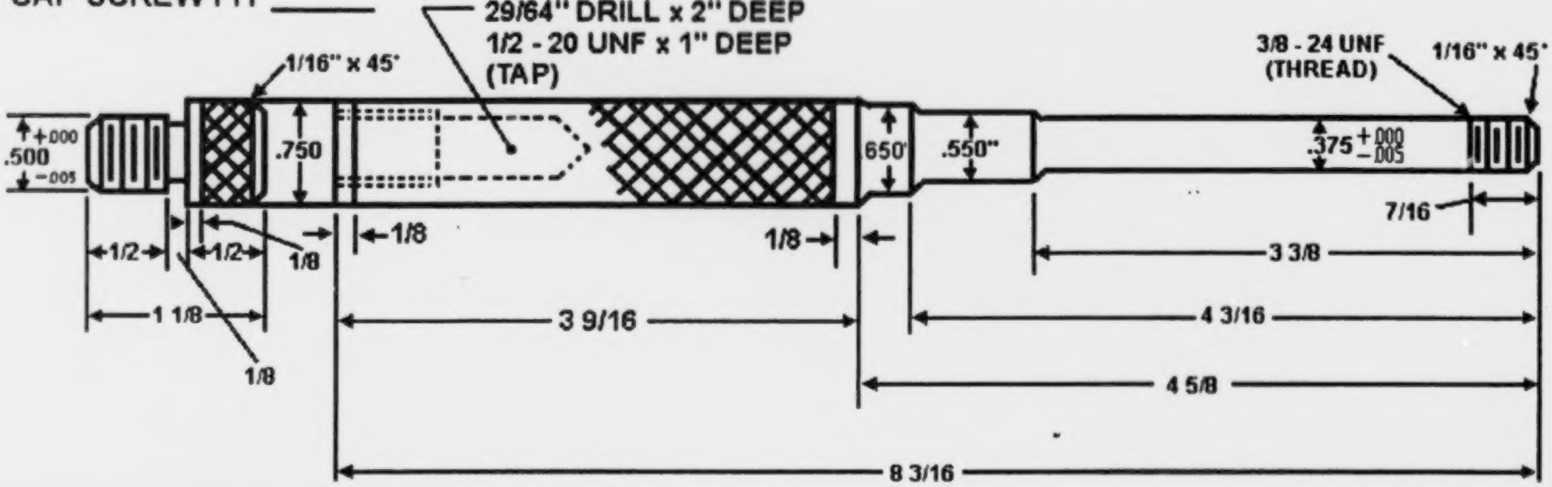
THREAD SQUARENESS: ____________

DIMENSIONS MISSED: ____________

SURFACE FINISH: ____________

TOLERANCES: FRACTIONS ± 1/64"
DECIMALS ± .005"

CAP SCREW FIT ______

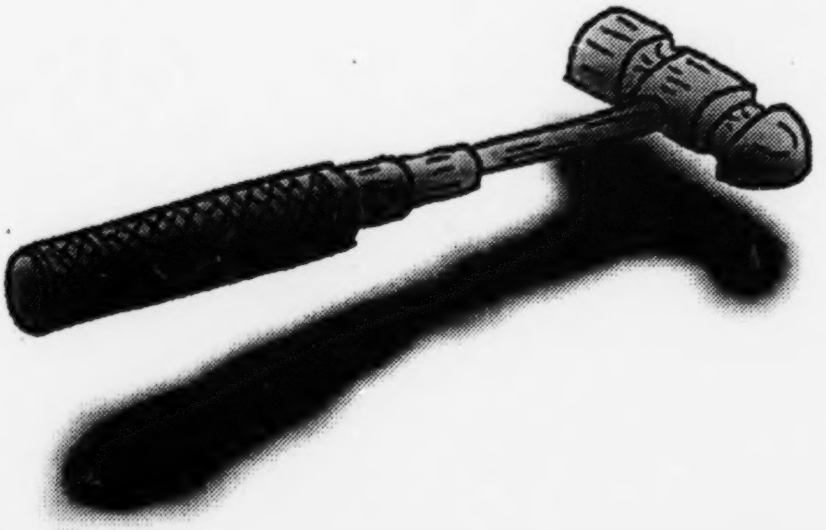

29/64" DRILL x 2" DEEP
1/2 - 20 UNF x 1" DEEP
(TAP)
1/16" x 45°
.500 +.000 −.005
.750
.650
.550"
3/8 - 24 UNF
(THREAD)
1/16" x 45°
.375 +.000 −.005
7/16
1/2
1/2
1/8
1/8
1/8
1/8
1 1/8
1/8
3 9/16
3 3/8
4 3/16
4 5/8
8 3/16

HANDLE

MATERIAL

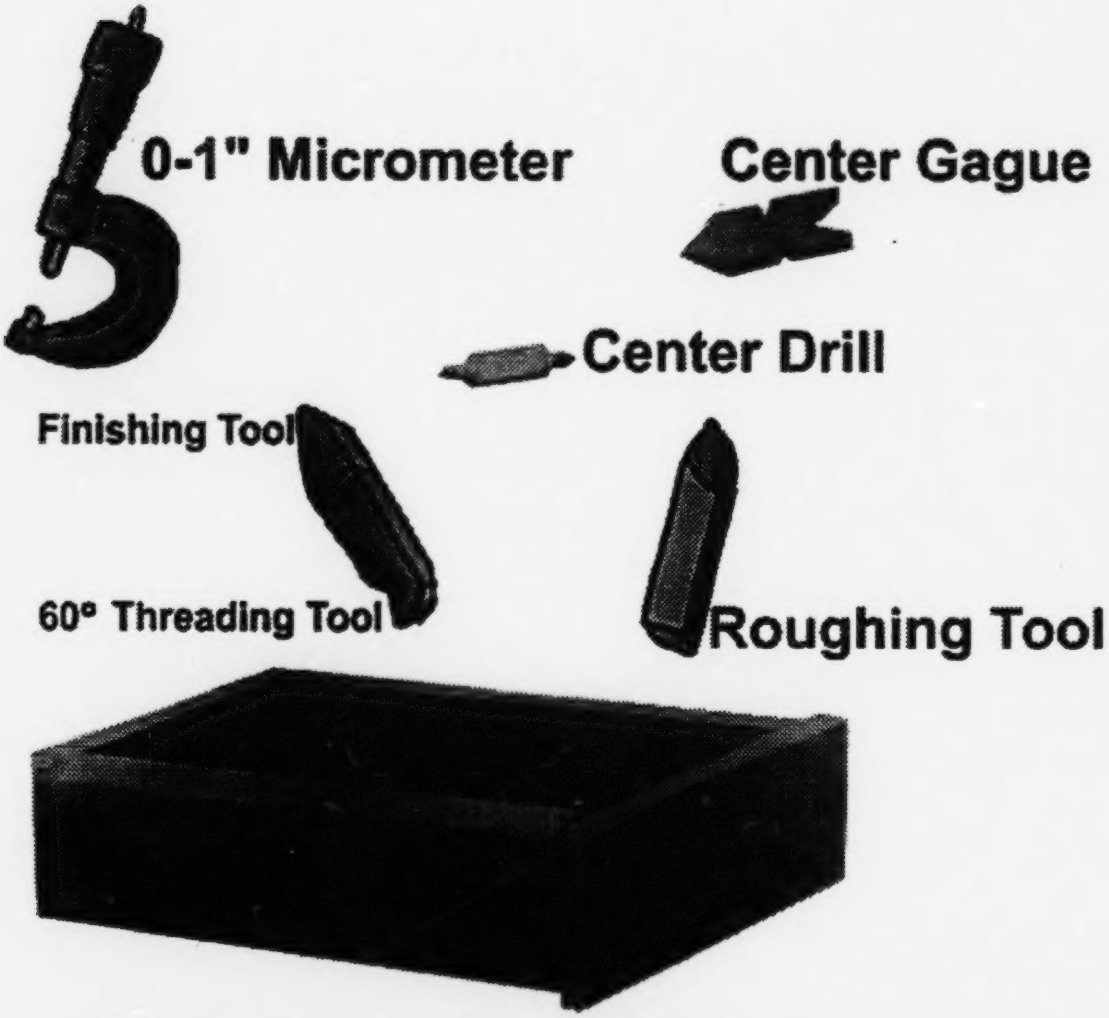
HEAD 4140 - HANDLE - C.R.S. 12 L 14

BALL PEEN HAMMER



Objectives:

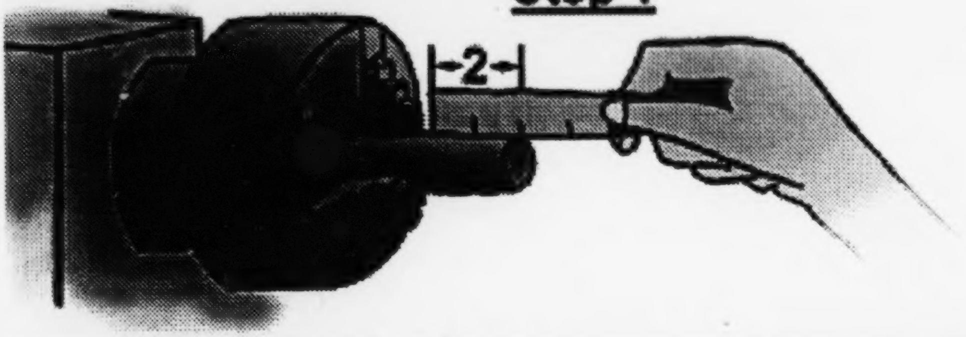
1. Become accquainted with work done in a machine shop.
2. Practice Engine Lathe Operation.
3. Observe the need for careful measuring.
4. See first hand the need for shop safety.

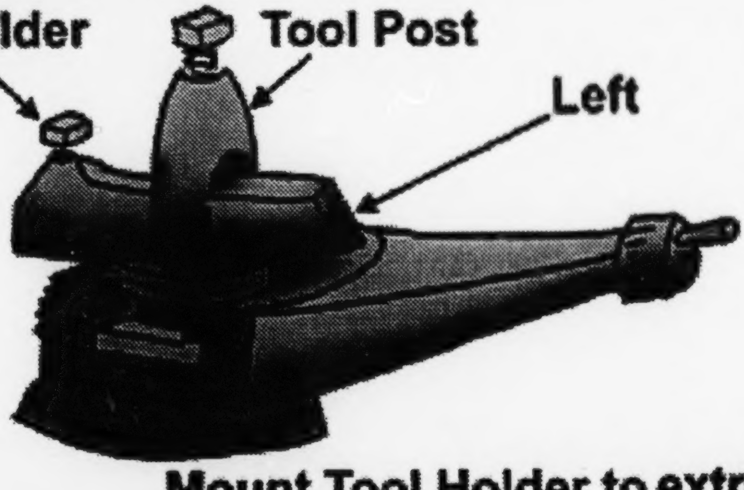

0-1" Micrometer
Center Gague
Center Drill
Finishing Tool
60° Threading Tool
Roughing Tool

These tools should be in your box.

General Information

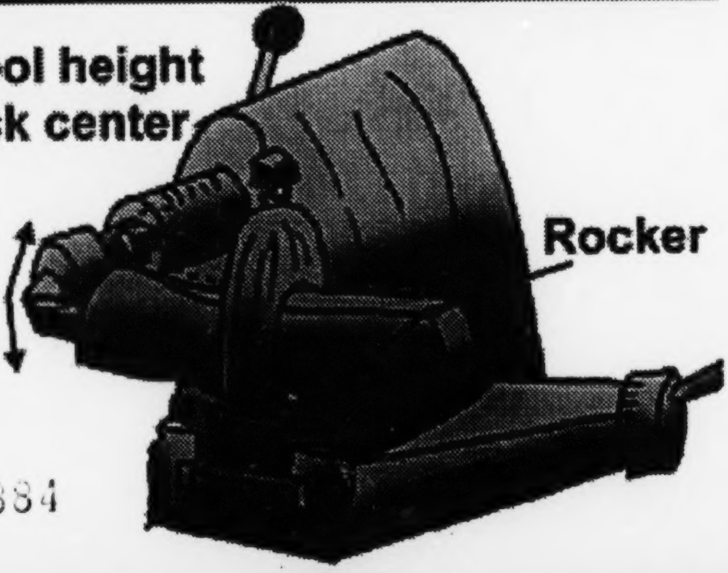
Step 1

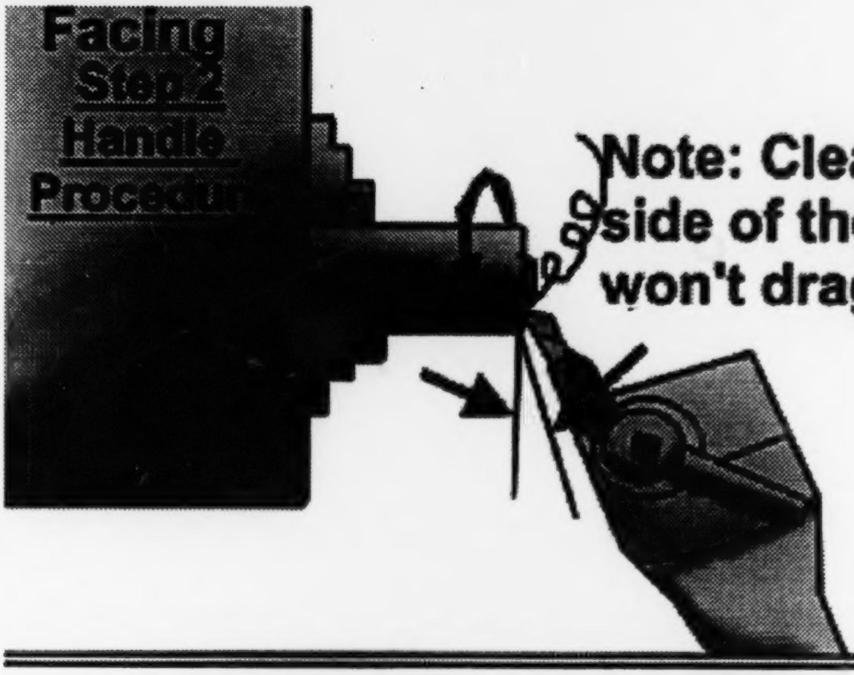



Tool Holder
Tool Post
Left

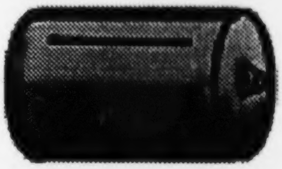
Mount Tool Holder to extreme left.

Setting cutting tool height Using the tailstock center as a guide.

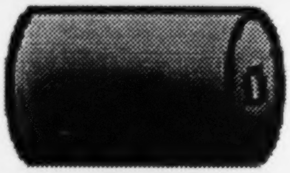



Facing
Step 2
Handle
Procedu

Note: Clearance so side of the tool won't drag on work.

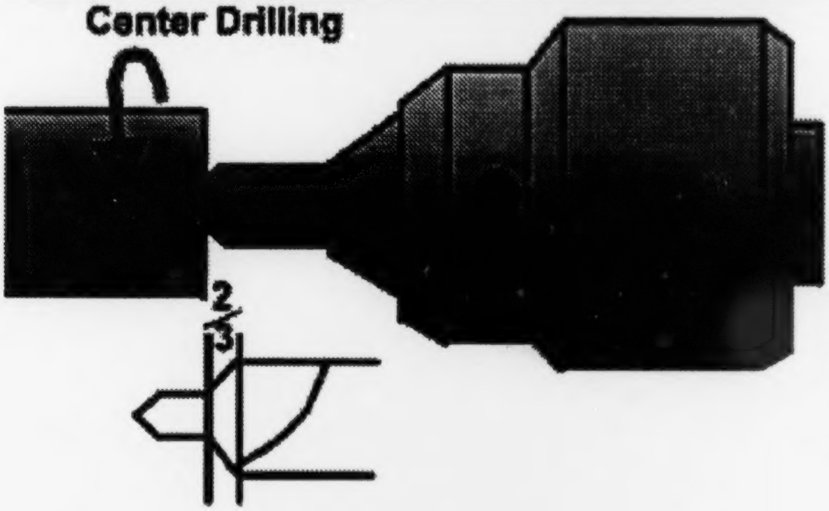


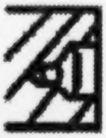
Point, Tool too Low.



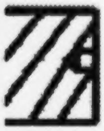
Rough, Tool too High.

Center Drilling

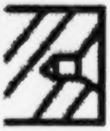




Too Deep

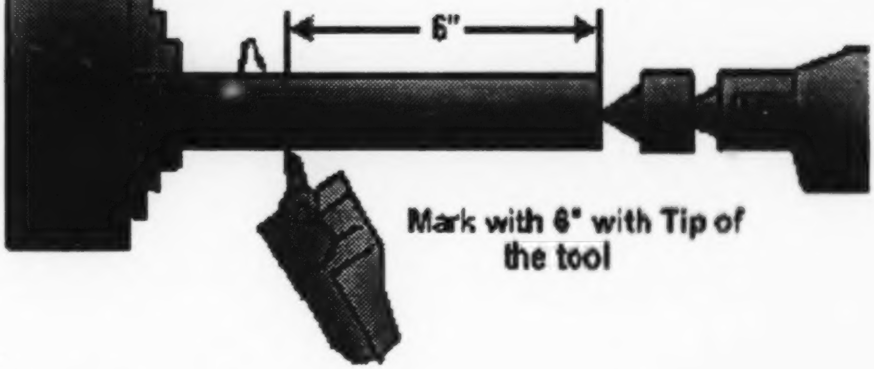


Too Shallow

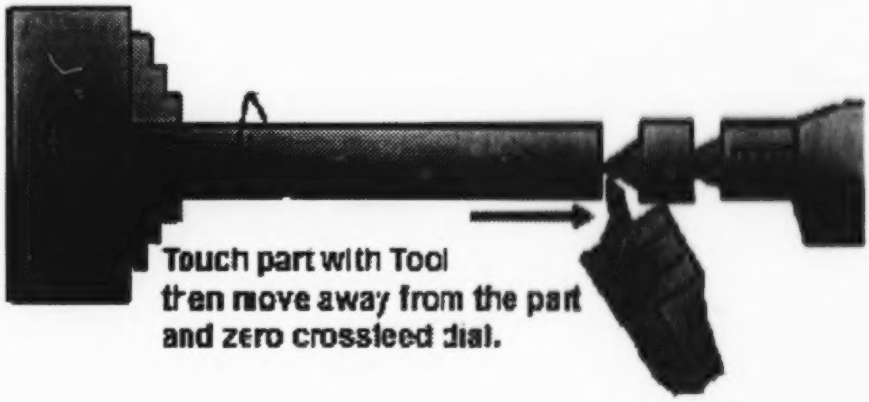


Correct

Step 4

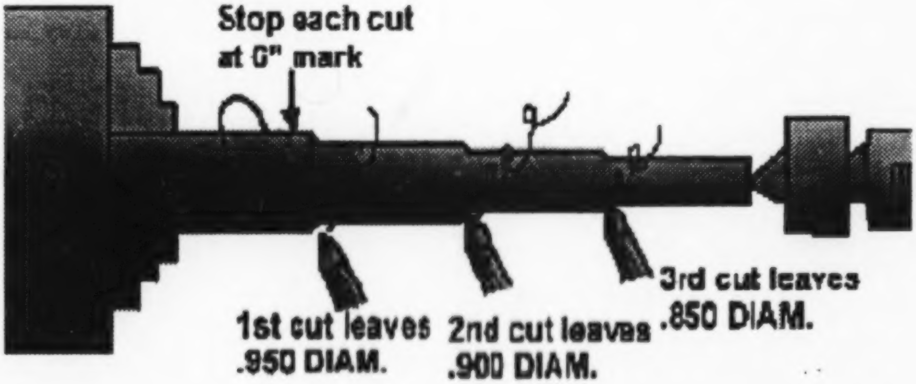


Mark with 6" with Tip of the tool



Touch part with Tool
then move away from the part
and zero crossfeed dial.

STEP 5



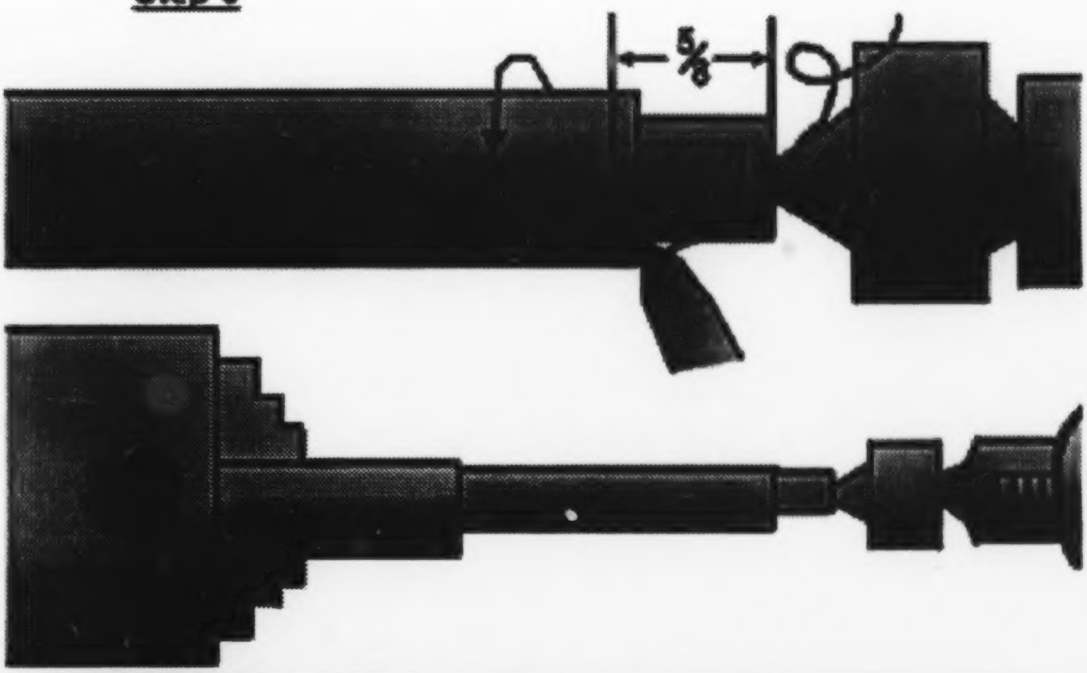
Stop each cut at 6" mark

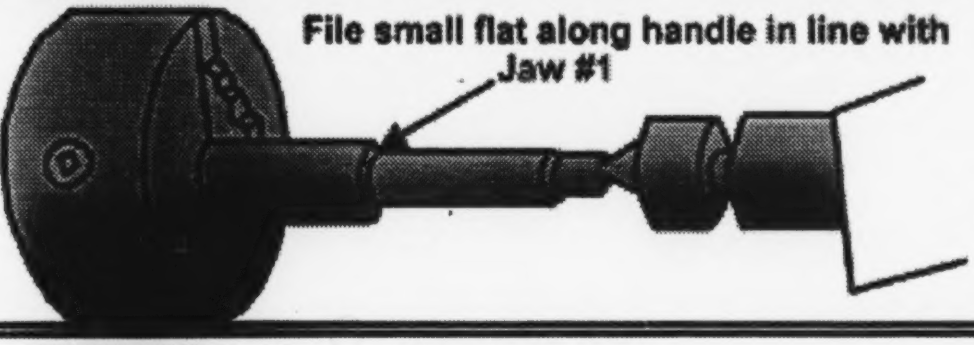
1st cut leaves .950 DIAM.

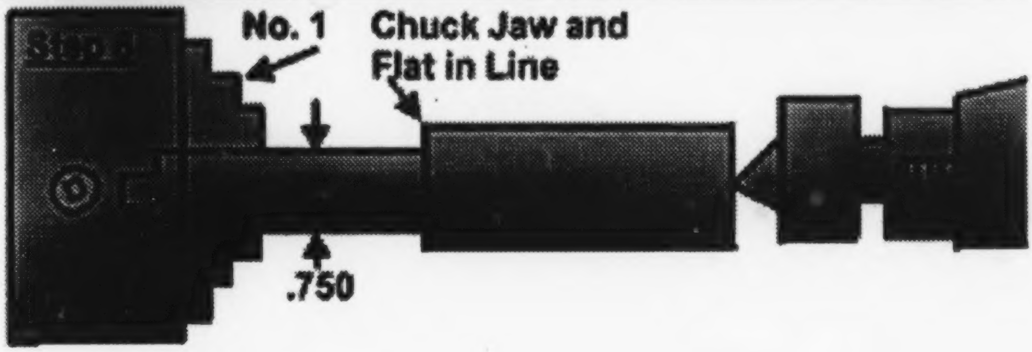
2nd cut leaves .900 DIAM.

3rd cut leaves .850 DIAM.

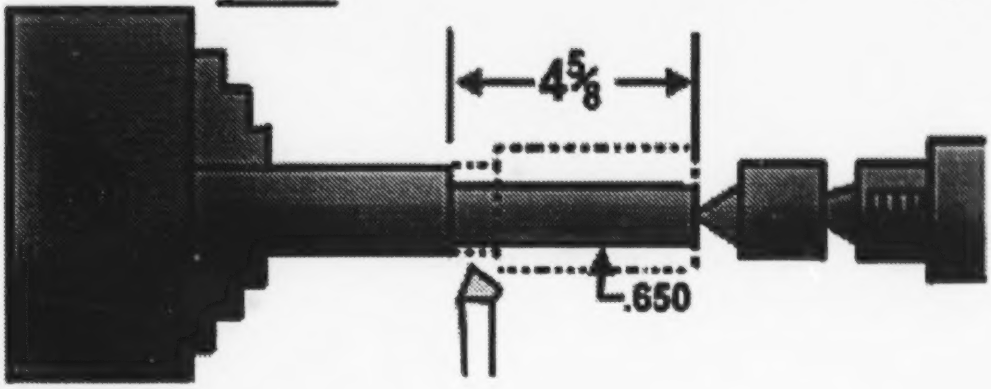
Step 6


5/8

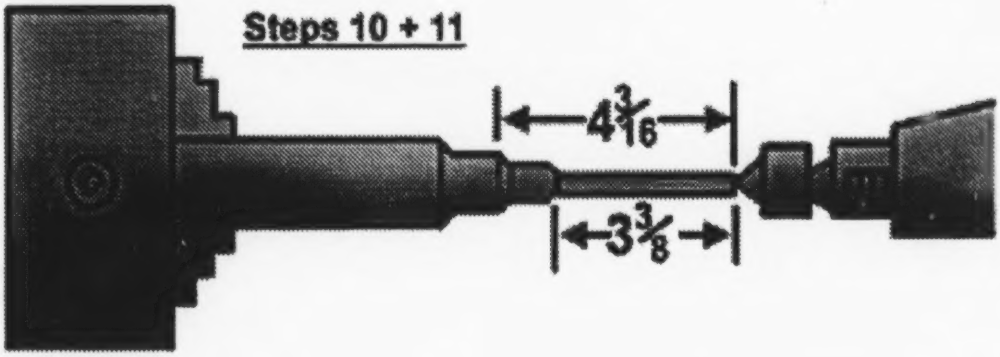

File small flat along handle in line with Jaw #1

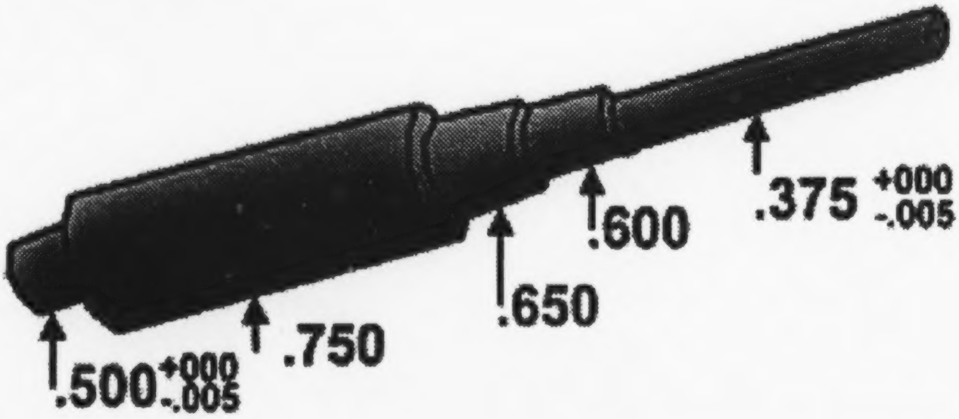

Step 6
No. 1
Chuck Jaw and Flat in Line
.750

STEP 9

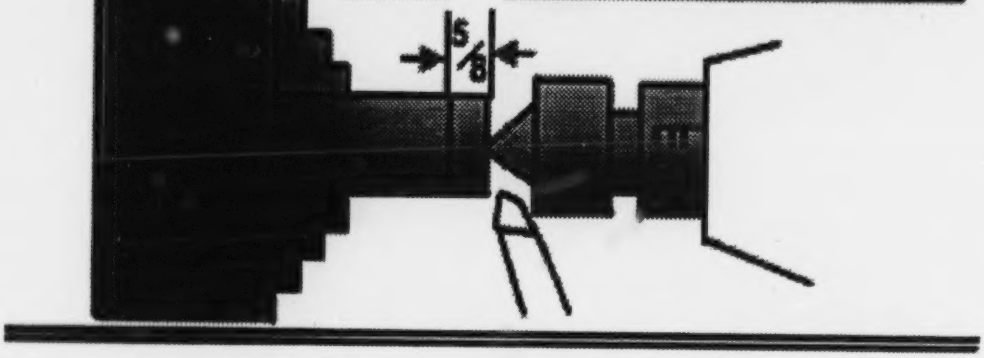


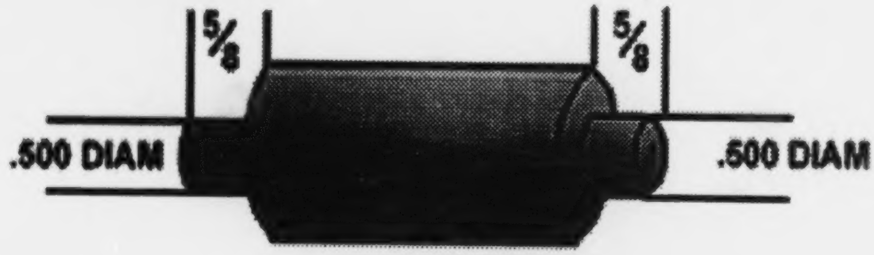
Steps 10 + 11

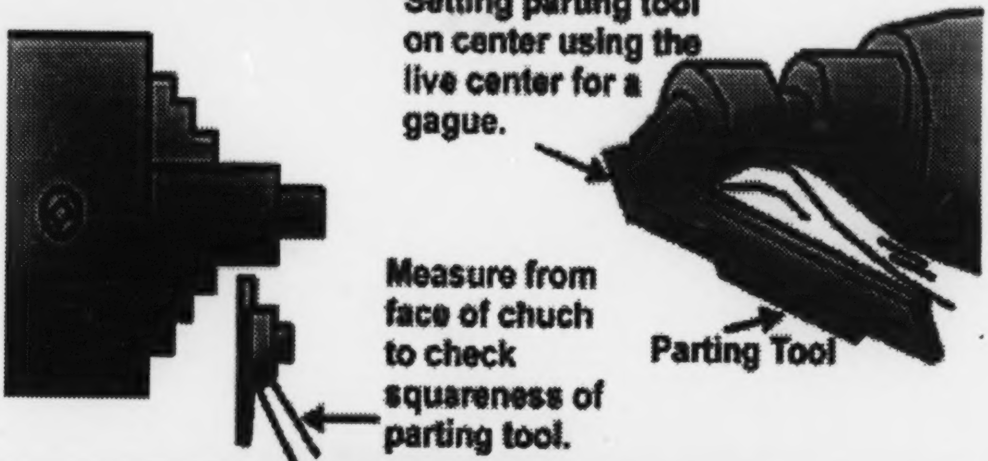



.500 +000 -.005
.750
.650
.600
.375 +000 -.005

STEP 3 HAMMER HEAD PROCEDURE

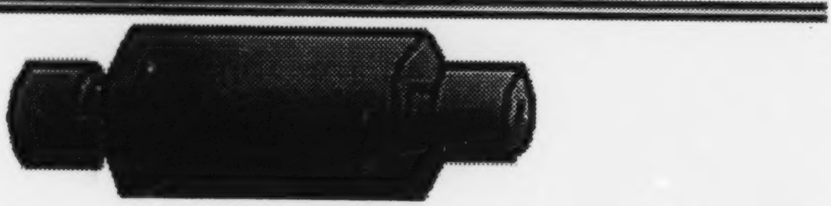



5/8
5/8
.500 DIAM
.500 DIAM

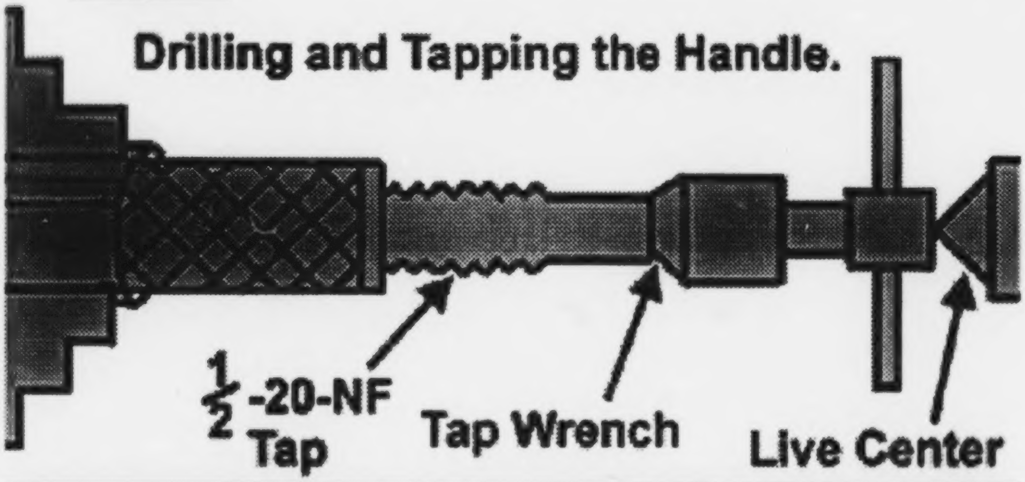

Setting parting tool on center using the live center for a gague.

Measure from face of chuch to check squareness of parting tool.

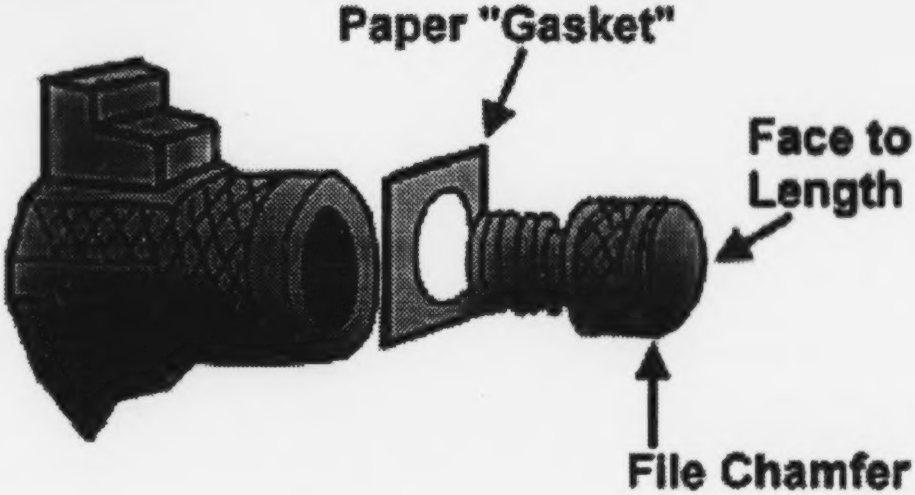
Parting Tool

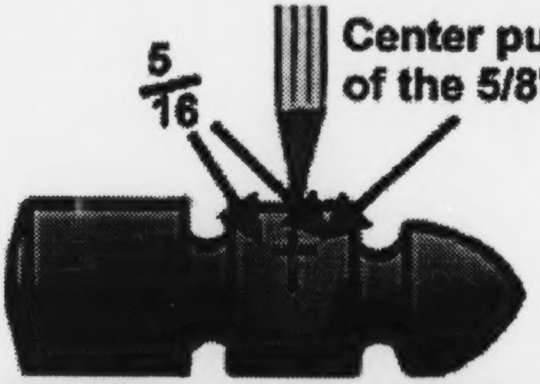


STEP 4

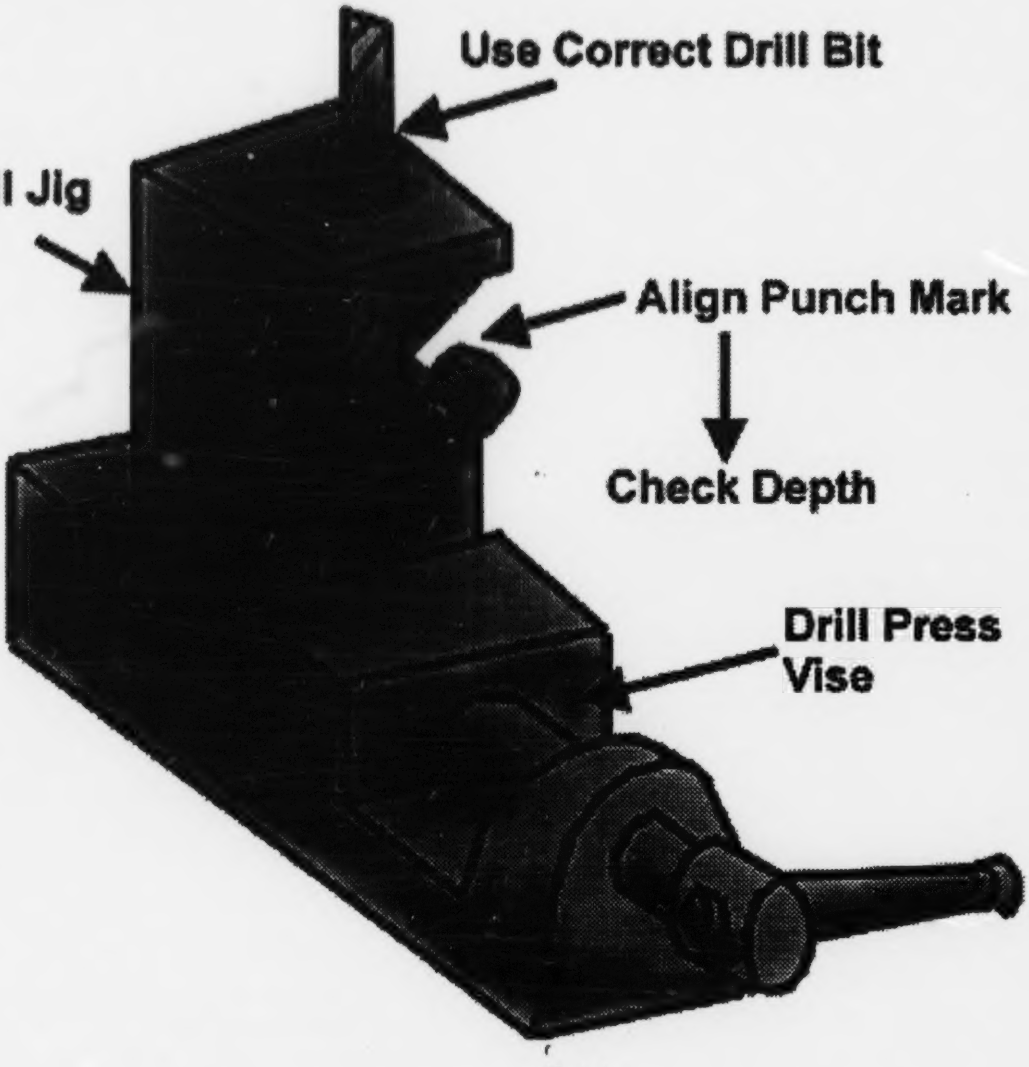

Drilling and Tapping the Handle.
$\frac{1}{2}$-20-NF Tap
Tap Wrench
Live Center

STEPS 5+6


Paper "Gasket"
Face to Length
File Chamfer



Center punch in the Center of the 5/8" wide section.



Use Correct Drill Bit

Drill Jig

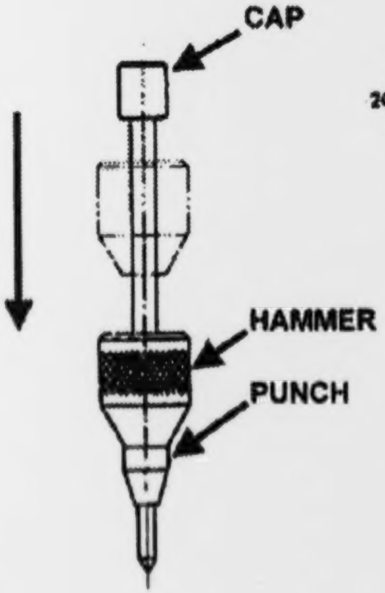
Align Punch Mark

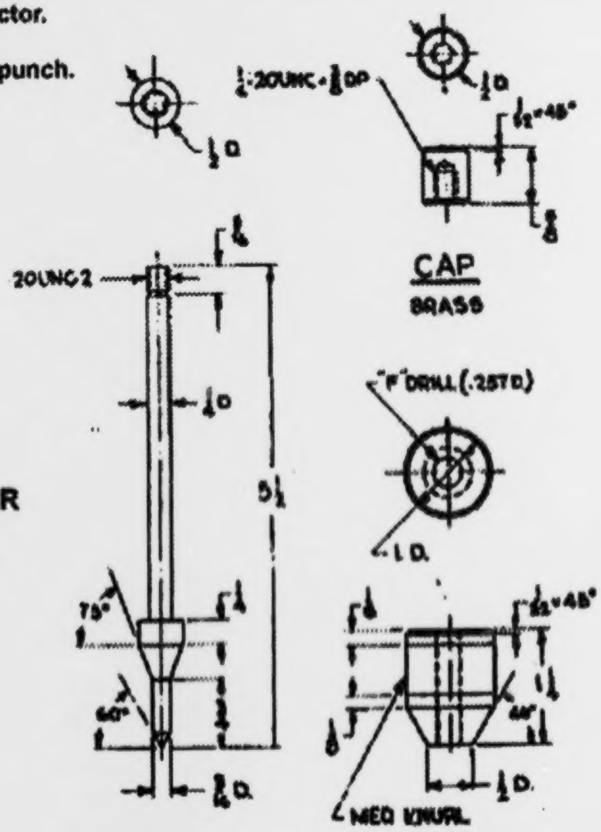
Check Depth

Drill Press Vise

GRAVITY CENTER PUNCH

1. Material: As noted.
2. Finish: Accepted machine shop practice
   little or no filing.
3. Tolerances: As indicated by your instructor.
4. Break all sharp edges.
5. Heat Treat only the point section of the punch.


CAP
HAMMER
PUNCH


1/4-20UNC-3/8 DP
1/2 D
1/2 D
1/32 x 45°
3/8
1/8
20UNC 2
1/4 D
5 1/2
75°
1/4
60°
1/8 D.
CAP
BRASS
"F" DRILL (.257 D.)
1 D.
1/8
1/32 x 45°
1 1/4
45°
1/8
1/2 D.
MED KNURL

PUNCH
DRILL ROD - HEAT TREAT

HAMMER
C.R.S.

CNC-F7-LA
Operate Metal Cutting Lathes
Attachment 3: **MASTER** Laboratory Aid

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

CNC MACHINIST .... **programs, edits, sets up, and operates CNC lathes, mills and grinders to perform machining operations necessary to produce workpieces to referenced engineering standards.**

	Duties	Tasks												
A	Practice Safety	A-1 Follow safety manuals and all safety regulations/ requirements	A-2 Use protective equipment	A-3 Follow safe operating procedures for hand and machine tools	A-4 Maintain a clean and safe work environment	A-5 MSDS/ control chemical hazards								
B	Apply Mathematical Concepts	B-1 Perform basic arithmetic functions	B-2 Convert fractional/ decimals	B-3 Convert Metric/ English measurements	B-4 Perform basic algebraic operations	B-5 Use practical geometry	B-6 Understand basic trigonometry	B-7 Calculate speeds and feeds for machining	B-8 Use coordinate systems					
C	Interpret Engineering Drawings and Control Documents	C-1 Identify basic layout of drawings	C-2 Identify basic types of drawings	C-3 Review blueprint notes and dimensions	C-4 List the purpose of each type of drawing	C-5 Verify drawing elements	C-6 Practice Geometric Dimensioning and Tolerancing (GD&T)	C-7 Analyze bill of materials (BOM)	C-8 Describe the relationship of engineering drawings to planning	C-9 Understand and use quality systems	C-10 Verify standard requirements			
D	Recognize Different Manufacturing Materials and Processes	D-1 Identify materials with desired properties	D-2 Identify materials and processes to produce a part	D-3 Describe the heat treating process	D-4 Test metal samples for hardness	D-5 Understand welding operations								
E	Measure/ Inspect	E-1 Understand metrology terms	E-2 Select measurement tools	E-3 Measure with hand held instruments	E-4 Eliminate measurement variables	E-5 Measure/ inspect using surface plate and accessories	E-6 Inspect using stationary equipment							
F	Perform Conventional Machining	F-1 Prepare and plan for machining operations	F-2 Use hand tools	F-3 Operate power saws	F-4 Operate drill presses	F-5 Operate vertical milling machines	F-6 Operate horizontal milling machines	F-7 Operate metal cutting lathes	F-8 Operate grinding/ abrasive machines					
G	Perform Advanced Machining	G-1 Understand CNC basics	G-2 Program CNC machines	G-3 Operate CNC machining centers (mills)	G-4 Operate CNC turning centers (lathes)									
H	Use Verification and Communication Systems	H-1 Use personal computer	H-2 Use various operating systems	H-3 Use computer communications systems	H-4 Use verification systems	H-5 Use the Internet								
I	Program Using CAM System	I-1 Understand CAD/ CAM programs	I-2 Manipulate CAD functions	I-3 Process simple tool-path data	I-4 Create advanced surface models	I-5 Process complex tool-path functions								

CNC-G1-HO
Understand CNC Basics
Attachment 1: MASTER Handout

Objectives:

Upon completion of this module the student will be able to:

a. Identify and describe essentials and safety of CNC systems;
b. Identify and describe types of CNC hardware and software;
c. Identify and describe machine axes and coordinate systems; and,
d. Identify and describe coordinate systems.

Module Outline:

I. Identify and Describe Essentials and Safety of CNC Systems
  A. Identify and explain essentials
    1. Define numerical control
    2. Explain history and future of CNC technology
    3. Identify basic elements of CNC system
    4. Define Computer Numerical Control (CNC)
    5. Explain advantages and limitations of CNC
    6. Identify applications of CNC technology
  B. Compare types of CNC systems
    1. Identify and describe modes on numerical control systems
    2. Explain difference between the following:
      a. Point-to-point
      b. Axial path
      c. 45° line type
      d. Linear path
      e. Continuous path
    3. Describe CNC interpolation
    4. Identify types of CNC interpolations
    5. Explain difference between open loop and closed loop systems
    6. List benefits and problems of open and closed loop systems
  C. Demonstrate safety practices related to CNC systems
    1. Demonstrate safety practices, including:
      a. Safety guard/door interlocks
      b. Power box interlocks
      c. Tool loading and unloading
      d. Loading and unloading work holding devices
      e. Machine coolant disposal
    2. Describe/identify personal safety equipment
II. Identify and Describe Types of CNC Hardware and Software
  A. Identify and describe CNC hardware

        1. Compare NC and CNC systems
        2. Identify components of CNC machine control unit (MCU)
        3. Define applications of operator control panel
        4. Explain functions of operator control panel
        5. Define utilities found on typical control panel
        6. Select appropriate CNC controls
    B. Describe CNC software
        1. Describe software related to machine tool
        2. Describe applications of operation, interface and application software
        3. Describe interface of software and hardware
    C. Explain feed back drive system
        1. Describe feed drive system
        2. Explain feed back mechanisms
        3. Compare direct and indirect measurement systems
III. Identify and Describe Machine Axes and Coordinate Systems
    A. Identify and describe machine axes
        1. Define and identify machine axes X, Y and Z
        2. Identify and describe linear axes using right hand rule
        3. Identify and define primary rotary axes A, B and C
    B. Describe coordinate systems
        1. Describe Cartesian coordinate system as used in NC program
        2. Define relationship of Cartesian coordinate system with machine axes
    C. Define characteristics of positioning systems
        1. Define application of absolute positioning systems
        2. Define application of incremental positioning systems
    D. Define reference systems
        1. Describe characteristics of:
            a. Machine reference coordinates
            b. Work reference coordinates
            c. Program reference coordinates
            d. Fixtures offset coordinates
IV. Describe and Interpret CNC Coding Systems
    A. Interpret number bases
        1. Interpret decimal and binary bases
        2. Interpret octal and hexadecimal bases
    B. Describe NC program storage media
        1. Describe the media
        2. Describe advantages and disadvantages of each media
    C. Describe EIA and ASCII formatted tapes
        1. Describe EIA format on tapes
        2. Describe ASCII format on tapes
        3. Describe differences in EIA and ASCII formats

CNC-G2-HO
Program CNC Machines
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this module the student will be able to:

a. Identify and describe the effects of material preparation to production;
b. Identify and describe the use of machine tool fixtures;
c. Identify and describe clamping principles and cautions;
d. Identify and describe the process of selecting proper cutting tools;
e. Identify and describe commonly used "G"codes;
f. Identify and describe commonly used "M"codes;
g. Calculate and program cutter speed and feeds, and depth of cut;
h. Describe and apply cutter compensation;
i. Identify and describe fixed cycles; and,
j. Trouble shoot common programming problems.

Module Outline:

I. Plan Process for NC Operations
  A. Plan for raw material preparation
    1. Describe effect of material preparation on production
    2. Describe typical shapes of raw materials
    3. Describe effects of proper material preparation
    4. Describe ways to minimize wasted time and material
    5. Describe pre-machining of materials to avoid excessive CNC machine time
    6. Create material preparation plan for NC machining
  B. Plan use of machining fixtures
    1. Describe and identify various work holding devices
    2. Describe clamping principles and cautions
    3. Describe work piece locating principles
    4. Create plan for work holding devices and tooling selection on program planning sheet
  C. Select proper cutting tools
    1. List common types of tool alloys used for cutting tools
    2. Identify advantages and disadvantages of different alloys
    3. Evaluate prices for various alloys compared to productivity changes
    4. Compare various tool geometries and their effects on machining
    5. Select tooling based on various budget models
    6. Create tool planning list showing various models
II. Write NC Programs

A. Create NC words
    1. Define NC characters, blocks and words
    2. Identify and describe commonly used NC codes
    3. Describe and create safe start blocks
    4. Combine NC codes to create part program
B. Create NC programs
    1. Use absolute (G90) and incremental (G91) positioning
    2. Use rapid positioning (G00) and linear interpolation (G01)
    3. Use circular interpolation (G02) and (G03)
    4. Identify plane selections (G17, G18, G19)
C. Apply proper plane selection to circular interpolation
    1. Define and describe axis modifiers (I, J, K)
    2. Apply to circular interpolation (absolute and incremental type)
D. Calculate and program cutter speed and cutter compensation
    1. Describe cutter compensation commands (G40, G41, G42)
    2. Describe relationships associated with G41 and climb milling
    3. Describe relationship associated with G42 and conventional milling
E. Evaluate reference documentation to establish machinability factors for RPM equation
    1. Apply RPM calculations to identify proper spindle speed "S" word
    2. Calculate and program cutter feed and depth of cut
    3. Evaluate reference documentation to establish feed rate factors
    4. Apply depth of cut calculations for programming efficiency
    5. Apply feed equation to establish correct feed "F" word
F. Program tool selection and unit input systems
    1. Describe and apply unit input code (G70 and G71) correctly
    2. Describe tool function "T" word and its use
    3. Describe retract quill to Z machine home "M6"
    5. Describe and apply "T" word with "M6" to create tool change
G. Apply "M" codes to program
    1. Describe and list common "M" words and their applications
    2. Describe "M00" program stop and "M01" optional stop applications
    3. Describe "M02" end of program and "M30" end of tape
H. Program spindle operation
    1. Identify spindle commands
    2. Describe "M03" spindle on clockwise and "M04" spindle on counterclockwise
    3. Describe "M05" stop spindle
    4. Identify and describe coolant commands "M07", "M08" and "M09"
    5. Apply "M" codes to program
I. Program fixed cycles

    1. Identify and describe fixed cycles “G81 - G89”
    2. Describe benefits and time saving by using fixed cycles in programming
    3. Explain different fixed cycle formats for different controllers
    4. Apply fixed cycles to programs

J. Program operator messages

    1. Identify and describe non-machine code “operator messages”
    2. Describe symbols to isolate operator messages from program
        a. “*”
        b. “( )”

K. Apply operator messages to NC part program as needed

CNC-G2-LE
Program CNC Machines
Attachment 2: MASTER Laboratory Exercise

The student will:

1. Create a basic tooling list and have the students (in teams) cost out and justify the tooling for the list. As you are doing this, have them debate the use of tooling fixtures from the perspective of cost and the effect on production. Have them cost out a simple tooling fixture and decide at what level of production it is cost effective.

2. Create a drawing that incorporates the most common moves that your equipment has available and also what is common in your area, this will give the students a basic program to write and see what it actually does. I have my students calculate the cutter compensation for their first program instead of using G41/G42; this reinforces their math skills. I also don't allow them to use .the "Fixed" cycles in their first program. This helps them reinforce their basic programming codes.

3. Have the students present their programs to the class at various stages of completion; as a group they can troubleshoot possible problems.

CNC-G3-HO
Operate CNC Machining Centers (Mills)
Attachment 1: MASTER Handout

Objectives:

Upon completion of this module the student will be able to:

a. Describe history of vertical machining;
b. Describe theory of operation;
c. Describe nomenclature used in vertical machining;
d. Demonstrate safety practices related to vertical machining centers;
e. Set-up and program operation of vertical machine;
f. Demonstrate proper machining of objects;
g. Create program using machine controllers software, and cycles;
h. Set-up and utilize three dimensional digitizer; and,
i. Maintain vertical machine.

Module Outline:

I. Describe Vertical Machining Process and Safety
  A. Describe history of vertical machining
    1. Describe proper use of various machines
  B. Describe theory of operation
    1. Describe open and closed loop systems
    2. Describe various oil and air requirements
    3. Describe how vertical machines function
  C. Describe nomenclature used in vertical machining
    1. Describe common tools used to:
      a. Mill
      b. Single point thread
      c. Drill
      d. Single point bore
      e. Tap
      f. Reaming
    2. Describe solid and collet type tool holders
  D. Demonstrate safety practices related to vertical machining centers
    1. Demonstrate operating safety practices, including:
      a. Safety door interlocks
      b. Machining vise loading and unloading
      c. Power box interlocks
      d. Machine coolant disposal
      e. Tool loading and unloading
    2. Describe/identify personal safety equipment
II. Describe Vertical Machining Functions

- A. Describe controller functions, including:
    - 1. Power meter
    - 2. Automatic mode
    - 3. Key lock
    - 4. Emergency stop button
    - 5. Option switches
    - 6. Manual modes:
        - a. Command mode
        - b. MDI mode
    - 7. Rapid travel over ride
    - 8. Single step mode (block-To-block)
    - 9. Feed rate override
    - 10. Jog mode
    - 11. Spindle speed override
    - 12. Spindle on/off
    - 13. Axis selector
    - 14. Slide hold
    - 15. Increment of movement selector
    - 16. Coolant 1 and 2 on/off
    - 17. Tool in/out
    - 18. Start button
    - 19. Turret clockwise (CW) and turret counterclockwise (CCW)
    - 20. Start function

III. Set-Up and Program Operation of Vertical Machine

- A. Describe machine tool limitations, including:
    - 1. Number of possible tools
    - 2. Limits in X,Y and Z axes
    - 3. Maximum spindle speed and horsepower
    - 4. Memory size in controller
    - 5. Fast feed rate
    - 6. Oil and air requirements
    - 7. Rapid positioning rate
    - 8. Communication systems
- B. Perform basic machine set-up
    - 1. Check oil and air supply
    - 2. Set tool changer numbers
    - 3. Turn power on
    - 4. Mount machine vise on machine table
    - 5. Set machine home position
    - 6. Indicate vise to within specified tolerances
    - 7. Load tools into proper tool holders
    - 8. Load part into vise
    - 9. Load tools into tool carousel
        - a. Load tools using spindle
        - b. Load tools directly into carousel

C. Set part home
   1. Set part home using edge finder
   2. Set part home using test indicator and gauge block
   3. Set part home from tooling ball using fixture offsets

D. Set tool length offsets
   1. Set tool length offsets using work piece
   2. Set tool length offsets using gauge block
   3. Set tool length offsets using electronic probe
   4. Set tool length offsets using keyboard commands
   5. Modify length and diameter offsets using tool page editor.
   6. Upload and download tool information to storage

E. Load program
   1. Upload and download programs using RS-232 interface
   2. Upload and download programs using local area network

F. Edit program for machine tool
   1. Edit program at machine tool using editor in controller
   2. Edit program using DOS and Windows editors

G. Create program without CAD/CAM for common machine operations using machine controllers software to include:
   1. Proper use of cutter compensation
   2. Fixed cycles
   3. Fixed sub-routines
   4. Sub-routines (loops)
   5. Fixture offsets
   6. Troubleshoot and repair problems in programs
   7. Use machine verification options if available

IV. Demonstrate Machining of Objects on Vertical Machining Center

A. Machine objects, including:
   1. Outside contours
   2. Pockets
   3. Drilled holes
   4. Drill and tapped holes
      a. Rigid tapping
      b. Compression tapping
   5. Single point boring
   6. Reaming
   7. Single point thread, internal and external

B. Set-up three dimensional digitizer and machine model
   1. Mount model on machine table
   2. Install 3-dimensional digitizing unit
   3. Establish communications with computer
   4. Define grid pattern and feed rate required for given tolerances
   5. Set part home
   6. Digitize model
   7. Process digital data for machining

8. Machine new model with program created from digitizer

C. Create work piece using 4th- and 5th-axes
    1. Mount, connect and indicate 4th- and 5th-axes attachment
    2. Set-tooling
    3. Machine work piece
    4. Remove 4th- and 5th-axes attachment

D. Maintain vertical machine
    1. Mix coolant
    2. Determine need for coolant change
    3. Change coolant
    4. Clean coolant tank
    5. Clean machine
    6. Change oil filters
    7. Add lubricating fluid
    8. Add hydraulic fluid
    9. Dispose of coolant and oils per EPA regulations

CNC-G4-HO
Operate CNC Turning Centers (Lathes)
Attachment 1: MASTER Handout

Objectives:

Upon completion of this module the student will be able to:

- a. Describe history of horizontal turning centers;
- b. Describe theory of operation;
- c. Describe nomenclature used in horizontal turning centers;
- d. Demonstrate safety practices related to horizontal turning centers;
- e. Set-up and program operation of horizontal turning centers;
- f. Demonstrate proper machining of objects;
- g. Create program using machine controllers software; and,
- h. Maintain horizontal turning centers.

Module Outline:

- I. Explain CNC Turning Process, Equipment and Safety
  - A. Describe CNC turning process
    - 1. Describe history of CNC turning
    - 2. Describe use of various turning machines
  - B. Describe theory of operation
    - 1. Describe open and closed loop systems
    - 2. Describe various oil and air requirements
    - 3. Describe how turning centers function
  - C. Describe nomenclature used in CNC turning
    - 1. Describe and identify common tools used to:
      - a. Turn
      - b. Drill
      - c. Groove
      - d. Face
      - e. Bore
      - f. Single point thread
      - g. Tap
    - 2. Describe and identify work holding devices used in turning, including:
      - a. 2-jaw chucks
      - b. 3-jaw chuck
      - c. 4-jaw chucks
      - d. Soft jaw chucks
      - e. Bar feed attachments
      - f. Collets
      - g. Centers

      3. Select proper cutting inserts relative to:
         a. Roughing
         b. Finishing
         c. Threading
         d. Different types of materials
   D. Demonstrate safety practices related to CNC turning centers
      1. Demonstrate operating safety practices, including:
         a. Safety door interlocks
         b. Power box interlocks
         c. Tool loading and unloading
         d. Loading and unloading work holding devices
         e. Machine coolant disposal
      2. Describe/identify personal safety equipment

II. Describe CNC Turning Center
   A. Describe controller functions, including:
      1. Power meter
      2. Option switches
      3. Key lock
      4. Emergency stop button
      5. Rapid travel override
      6. Feed rate override
      7. Spindle speed override
      8. Axis selector
      9. Increment of movement selector
      10. Slide hold
      11. Start function
   B. Describe keyboard functions, including:
      1. Automatic mode
      2. Manual MDI mode
      3. Single step mode (block-to-block)
      4. Jog mode
      5. Spindle on/off
      6. Coolant on/off
      7. Tool turret clockwise (CW) and tool turret counterclockwise (CCW)

III. Set-Up and Program Operation of CNC Turning Center
   A. Describe machine tool limitations, including:
      1. Number of possible tools
      2. Maximum spindle speed and horsepower
      3. Fast feed rate
      4. Rapid positioning rate
      5. Limits in X and Z axes
      6. Memory size in controller
      7. Oil and air requirements
      8. Communication systems

- B. Perform basic machine set-up
    1. Check oil and air supply
    2. Turn power on
    3. Set machine home position
    4. Load tools into proper tool holders
    5. Load tools into tool carousel
    6. Set tool changer numbers
    7. Mount work piece into chuck
    8. Indicate work piece within specified tolerances
- C. Set tool length offsets
    1. Set tool length offsets using work piece
    2. Set tool length offsets using keyboard commands
    3. Modify length and diameter offsets using tool page editor
    4. Modify length and diameter offsets using keyboard
    5. Upload and download tool information to storage
- D. Load program
    1. Upload and download programs using RS-232 interface
    2. Upload and download programs using local area network
- E. Edit program for machine tool
    1. Edit program at machine tool using editor in controller
    2. Edit program using DOS and Windows editors

IV. Create Program Without CAD/CAM for Common Machine Operations Using Machine Controllers Software to include:
- A. Proper use of cutter compensation
- B. Fixed cycles
- C. Fixed sub-routines
- D. Sub-routines (loops)
- E. Fixture offsets
- F. Trouble shoot and repair problems in programs
- G. Use machine verification options if available

V. Create Program for Common Machine Operations
- A. Use machine controller editor
- B. Use DOS editor
- C. Use Windows editor

VI. Demonstrate Machining of Objects on CNC Turning Center
- A. Machine objects, including:
    1. External and internal contouring
    2. External and internal grooving
    3. Drill and tapped holes
    4. Single point boring
    5. Reaming
    6. Single point thread internal and external
    7. Facing operations
    8. Turning tapers
- B. Maintain turning center

1. Mix coolant
2. Determine need for coolant change
3. Change coolant
4. Clean coolant tank
5. Clean machine
6. Change oil filters
7. Add lubricating fluid
8. Add hydraulic fluid
9. Dispose of coolant and oils per EPA regulations

CNC MACHINIST .... **programs, edits, sets up, and operates CNC lathes, mills and grinders to perform machining operations necessary to produce workpieces to referenced engineering standards.**

	Duties	Tasks												
A	Practice Safety	A-1 Follow safety manuals and all safety regulations/ requirements	A-2 Use protective equipment	A-3 Follow safe operating procedures for hand and machine tools	A-4 Maintain a clean and safe work environment	A-5 MSDS/ control chemical hazards								
B	Apply Mathematical Concepts	B-1 Perform basic arithmetic functions	B-2 Convert fractions/ decimals	B-3 Convert Metric/ English measurements	B-4 Perform basic algebraic operations	B-5 Use practical geometry	B-6 Understand basic trigonometry	B-7 Calculate speeds and feeds for machining	B-8 Use coordinate systems					
C	Interpret Engineering Drawings and Control Documents	C-1 Identify basic layout of drawings	C-2 Identify basic types of drawings	C-3 Review blueprint notes and dimensions	C-4 List the purpose of each type of drawing	C-5 Verify drawing elements	C-6 Practice Geometric Dimensioning and Tolerancing (GD&T)	C-7 Analyze bill of materials (BOM)	C-8 Describe the relationship of engineering drawings to planning	C-9 Understand and use quality systems	C-10 Verify standard requirements			
D	Recognize Different Manufacturing Materials and Processes	D-1 Identify materials with desired properties	D-2 Identify materials and processes to produce a part	D-3 Describe the heat treating process	D-4 Test metal samples for hardness	D-5 Understand welding operations								
E	Measure/ Inspect	E-1 Understand metrology terms	E-2 Select measurement tools	E-3 Measure with hand held instruments	E-4 Eliminate measurement variables	E-5 Measure/ inspect using surface plate and accessories	E-6 Inspect using stationary equipment							
F	Perform Conventional Machining	F-1 Prepare and plan for machining operations	F-2 Use hand tools	F-3 Operate power saws	F-4 Operate drill presses	F-5 Operate vertical milling machines	F-6 Operate horizontal milling machines	F-7 Operate metal cutting lathes	F-8 Operate grinding/ abrasive machines					
G	Perform Advanced Machining	G-1 Understand CNC basics	G-2 Program CNC machines	G-3 Operate CNC machining centers (mills)	G-4 Operate CNC turning centers (lathes)									
H	Use Verification and Communication Systems	H-1 Use personal computer	H-2 Use various operating systems	H-3 Use computer communications systems	H-4 Use verification systems	H-5 Use the Internet								
I	Program Using CAM System	I-1 Understand CAD/ CAM programs	I-2 Manipulate CAD functions	I-3 Process simple tool-path data	I-4 Create advanced surface models	I-5 Process complex tool-path functions								

CNC-H1-HO
Use Personal Computer
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this module the student will be able to:

a. Demonstrate proper use of personal computers;
b. Describe and identify various memory types and their functions;
c. Describe and identify main computer components and their applications; and,
d. Demonstrate ability to connect basic computer components.

Module Outline:

I. Demonstrate Use of Personal Computer
  A. Demonstrate use of computer hardware
    1. Describe and demonstrate the function and proper use of common computer components: (power switch, turbo switch, video monitor, keyboard, mouse, hard drive, floppy disk drive, printer & plotter, etc.)
    2. Describe and demonstrate proper computer use
      a. No food or drinks near computers
      b. No finger prints, or pen points on computer screens
      c. Proper cleaning of computer components to include:
        (1) Monitors
        (2) Keyboards
        (3) Mice
        (4) Disk drives

II. Describe and Identify Various Memory Types and Their Functions
  A. Read only memory "ROM"
  B. Random access memory "RAM"
  C. Hard disk
  D. Floppy disk: (5¼" DSDD, 5¼" DSHD, 3½" DSDD, 3½" DSHD)
    1. CD-Rom's
    2. Tape backups

III. Describe Main Computer Components and Their Application
  A. Motherboard
  B. Video card
  C. Processor
  D. Parallel ports
  E. Co-Processor
  F. Ram chips
  G. Serial ports

    - H. Mice
    - I. Modems
    - J. Network cards
    - K. CD-Rom
- IV. Demonstrate Ability to Connect Basic Computer Components
    - A. Monitor
    - B. Mouse
    - C. Computer (central processing unit)
    - D. Keyboard
    - E. Printer
    - F. Modem
    - G. Network cards
    - H. CD-Rom

CNC-H2-HO
Use Various Operating Systems
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this module the student will be able to:

a. Demonstrate a basic understanding of the common DOS commands;
b. Demonstrate a basic understanding of the common Windows commands;
c. Demonstrate a basic understanding of the common Windows NT commands; and,
d. Demonstrate a basic understanding of the common Windows 95 commands.

Module Outline:

I. Demonstrate Use of Basic DOS Commands
  A. Operate disk commands
    1. Format a floppy diskette
    2. Create boot disk (system disk)
    3. Change disk drives
  B. Operate view commands
    1. View file using DIR command and with pause (/p) and wide (/w) switches
    2. View directory using tree command
    3. View file using Dir command with:
      a. Filename and wildcards in place of extensions
      b. Extensions and wildcards in place of file names
      c. Filename and extension
  C. Create subdirectories and files
    1. Make subdirectory
    2. Identify and describe filename and extensions
    3. Create filename and extension using DOS editor
  D. Modify, move and copy files
    1. Modify existing file using DOS editor
    2. Explain path statements
    3. Copy file to another location using:
      a. Filename and extension
      b. Wildcards
      c. Wildcards and extensions in place of filename
      d. Filename and wildcards in place of extensions
    4. Delete or erase file using filename or extension
    5. Move file using:

            a. Filename and extensions
            b. Wildcards
            c. Wildcard and extensions in place of filename
            d. Filename and wildcards in place of extensions
        6. Copy file and directory using XCOPY command
        7. Create backup diskette using DISKCOPY command
        8. Change file name using RENAME command
        9. Change disk name using LABEL command
        10. Delete directory using REMOVE DIRECTORY command
        11. Create and modify batch files
    E. Set computer clock, date and time
        1. Set computer clock using TIME command
        2. Set computer calendar using DATE command
    F. Perform disk maintenance
        1. Optimize memory storage using CHKDSK /F and DEFRAG command
        2. Evaluate memory using CHKDSK
        3. Maintain memory disk using SCANDISK command
        4. Describe utility packages used for disk maintenance
II. Demonstrate Use of Windows, Windows NT, and Windows 95 Commands
    A. Manipulate program icons
        1. Logging onto a computer system
        2. Start windows
        3. Describe program icons / desktop
        4. Maximize and minimize program icons
        5. Describe and maximize main program group
    B. Use File Manager/ Windows Explorer functions
        1. Open File Manager / Windows Explorer
        2. Logging on (connecting) to a network system
        3. Change drive using drive buttons
        4. Pull down file selection using mouse
        5. Tag file groups using mouse and Select key
        6. Tag various files using mouse and CTRL key
    C. Move, copy and change files in file menu
        1. Move file using mouse to drag and drop
        2. Copy file using mouse to drag and drop
        3. Delete file using mouse
        4. Change filename and extension using RENAME command
        5. Change properties of file including: Read Only, Archive, System, Hidden
    D. Maintain and print directories and files
        1. Start an application from File Manager using Run
        2. Start an application from File Manager using double click mouse method
        3. Print file using PRINT command

    4. Connect files to applications using the ASSOCIATE command
    5. Create directories (parent and child) using CREATE DIRECTORIES command
    6. Search for "lost" files using SEARCH command, filename, extension and wildcard
  E. Use disk menu utilities
    1. Pull down disk menu using mouse
    2. Copy disk using COPY DISK command
    3. Change disk label using LABEL DISK command
    4. Format disk using FORMAT command
    5. Create system disk using FORMAT command
    6. Change drive using SELECT DRIVE command
  F. Manipulate view menu commands
    1. View files by filename, extensions and wildcards
    2. Display files showing all file details and partial file details
    3. Sort files by name, type, size and date
  G. Exit File Manager/Windows Explorer
    1. Exit file manager by double clicking control menu box with mouse
    2. Exit file manager by choosing exit from file menu selection

III. Demonstrate Use of Macros in Windows and Windows NT Programs
  A. Use basic Windows command macros
    1. Get help using the help key (F1)
    2. Close current application window (ALT + F4)
    3. Close Program Manager and exit Windows program (ALT + F4, ENTER)
    4. Close the current document window (CTRL + F4)
    5. Change a DOS application from full-screen view to window and back to full screen (ALT + ENTER)
    6. From DOS application open Control menu in Windows program (ALT + SPACE BAR)
    7. Send copy of current full-screen view of DOS text to Clipboard (PRINT SCREEN)
    8. Send a copy of current window to Clipboard (ALT + PRINT SCREEN)
  B. Switch task using Macros
    1. Bring up the Task List dialog box to display the list of the programs (CTRL + ESC)
    2. Cycle through the list of active tasks (ALT + TAB)
    3. Cycle through open windows and minimized programs (ALT + ESC)
  C. Use menu and submenu commands and options
    1. Highlight the first item on a menu bar (ALT or F10)
    2. Open and close a menu (ALT + UNDERLINE CHARACTER)
    3. Open and close a submenu (UNDERLINE CHARACTER)

4. Close a menu or submenu (ESC)
5. Open the Control menu of the current application window (ALT + SPACE BAR)
6. Open the Control menu of the current document window (ALT + HYPHEN)

D. Manipulate dialog box options
   1. Close and cancel a dialog box (ESC)
   2. Cycle forward through the options (TAB)
   3. Cycle backward through the options (SHIFT + TAB)
   4. Move to the first item in a list (HOME)
   5. Move to the last item in a list (END)
   6. Select all items in a list (CTRL + SLASH)
   7. Deselect all items in a list, except for the current selection (CTRL + BACKSLASH)
   8. Select the highlighted command button (ENTER)
   9. Toggle a highlighted check box (SPACE BAR)
   10. Choose option button and highlight item in a list (ARROW KEYS)
   11. Activate a command button containing an underlined character (ALT + UNDERLINED CHARACTER)
   12. Highlight an option containing an underlined character (ALT + UNDERLINED CHARACTER)
   13. Toggle a check-box item containing an underlined character (ALT + UNDERLINED CHARACTER)
   14. Select the option button containing an underlined character (ALT + UNDERLINED CHARACTER)
   15. Copy objects using (CTRL + C)
   16. Cut objects using (CTRL + X)
   17. Paste objects using (CTRL + V)

CNC-H3-HO
Use Computer Communications Systems
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this module the student will be able to:

a. Identify various methods of communicating with CNC machines;
b. Identify the various terminologies that apply to communication standards; and,
c. Demonstrate the ability to connect and configure a communications link.

Module Outline:

I. Demonstrate Use of Computer Communication Systems
  A. Describe theory of communication as related to:
    1. CNC machines
    2. Computer networks
  B. Describe the common terminology used in communications
    1. Formats:
      a. ASCII
      b. EIA
      c. BIN
      d. ISO
    2. Serial communications connections:
      a. Communications ports: COM1, COM2.....
        (1) Various plug sizes
        (2) Wiring diagram "pin outs"
    3. Communication speed "baud rate"
      a. Why use higher and lower rates
      b. What are the normal standards
      c. What limits the baud rate
    4. Communication parity
      a. Even
      b. Odd
      c. No parity
    5. Data and stop bit information
      a. Numbers and settings
    6. Terminal emulation mode
      a. Accessing machine controls from computer
  C. Punch and load tape medium
    1. Describe various standards of tape medium
    2. Punch tape to load program into machine

  3. Punch tape of edited program at machine

D. Use electronic communications to load CNC programs
  1. Download and upload CNC programs using:
    a. RS-232 interface
    b. Communication section of CAD/CAM software
    c. Windows software
    d. Local area networks
    e. Bi-directional communication (handshaking)
    f. Direct Numerical Control
    g. Distributive numerical control

CNC-H4-HO
Use Verification Systems
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this module the student will be able to:

a. Identify various methods of verifying CNC programs;
b. Describe various settings used in preparing software for use;
c. Demonstrate ability to start CNC verification programs;
d. Perform operations required in configuring software for operation;
e. Demonstrate ability to apply various options required for model inspection; and,
f. Demonstrate ability to save various graphic images of completed models.

Module Outline:

I. Demonstrate Ability to Start CNC Verification Programs
  A. Choose software for verification
    1. Describe verification process
    2. Describe traits of various software packages
    3. Explain applications of different software packages
    4. List and identify appropriate software packages based on:
      a. Overall cost
      b. Hardware requirements
      c. Project requirements
      d. Multi axes machining
      e. Milling or turning
      f. Operating system
    5. Describe and identify functions of file names and extensions
  B. Start conversion process of toolpath for verification programs
    1. Describe conversion process from NC program to verification format
    2. Start PC
    3. Start conversion process
    4. Answer questions required in conversion process

II. Program and Create CNC Verification Using "Vericut" by CG-Tech Inc.
  A. Describe verification software
    1. Start software
    2. Describe menu structure
    3. Describe file extension formats and uses
    4. Describe various sections of display
    5. Describe information displayed by software

B. Program material definitions using stock functions
  1. Identify stock selection
  2. Define type of material stock
  3. Define length, width and height of stock
  4. Load stock files
  5. Rotate stock as needed
  6. Translate part home position to stock location
  7. Use accept and cancel options

C. Program view using view functions
  1. Identify view icon
  2. Rotate light source for different effects
  3. Change shade types and explain results
  4. Change view scale and explain results
  5. Rotate view as required
  6. Use accept, cancel, window, and preview options

D. Select color using color selection functions
  1. Identify color selection
  2. Select choices in color menu to include shading calculation for best results
  3. Use accept or cancel options, as required
  4. Describe and explain choices used in selection(s)

E. Program cutting set-up using cut functions
  1. Identify cut selection
  2. Select choices in cut set-up menu to:
     a. Set resolution and describe results
     b. Set cutter display and describe results
  3. Describe skip cut question and result
  4. Define path and filename of TP (APT) file

F. Program snap shots using snap shot functions
  1. Identify snap shot icon
  2. Select choices in snap shot menu to:
     a. Define file extension typically used for different applications
     b. Load existing snapshot "picture" file
     c. Save single snapshot file
     d. Control snap shot frequency
  3. Use auto save features, as required
  4. Use auto-error detection

G. Create cross section using cross section functions
  1. Identify cross section selections
  2. Select choices in cross section menu to include:
     a. Cross sectioning by plane numbers
     b. Cross sectioning by plane type
     c. Define options choice

H. Manipulate zoom functions

1. Identify zoom selections
2. Select choices in zoom menu to include: zoom mode, zoom resolution, scale factors

I. Program views of model using model functions
   1. Identify model selections
   2. Select choices in model menu to include:
      a. Translucent, reverse, display and cut models

J. Program tool path using tool path functions
   1. Identify tool path control selections
   2. Select choices in tool path menu to include:
      a. Tool path code type
      b. Machine type (milling or turning)
      c. Multi-axis
      d. Rotational choices

K. Program use of tools using tool control functions
   1. Identify tool control selections
   2. Select choices in tool control menu to include:
      a. Cutter, shank and holder selections

L. Program playback of program using playback functions
   1. Identify playback selections
   2. Select choices in playback menu to:
      a. Record verification session
      b. Play back verification session
   3. Describe benefits and drawbacks of recorded sessions

M. Select and manipulate user file functions
   1. Identify user file selections
   2. Define reasons for using user files
   3. Select choices in user file menu to:
      a. Define file extension for user file information
      b. Save user file information
      c. Load existing user file information

N. Create graphic image using shade copy functions
   1. Identify shade copy selections
   2. Select choices in shade copy menu to include:
      a. Type of shade copy
      b. Auto save and error functions
      c. Shading method
      d. Page orientation
      e. Using the TIFF format
      f. Output device
      g. Using the EPSF format
      h. Retrieving, converting various graphic file formats

O. Analyze measurement using x-caliper functions
   1. Identify x-caliper selection
   2. Select choices in x-caliper menu to measure:

    - a. Distance and angles
    - b. Points
    - c. Stock thickness
    - d. Air thickness
    - e. Features
- P. Execute use of holding devices using fixture functions
  - 1. Identify fixture selection
  - 2. Select choices in fixture menu to include:
    - a. Import fixtures
    - b. Define path and file to import
    - c. Describe plus and minus for fixture display

III. Program CNC Verification Using Microcompatibles "N-SEE"
- A. Select pull-down menu program
  - 1. Start program
  - 2. Select and describe which format to verify:
    - a. NC code
    - b. Intermediate files
    - c. Describe strengths and limitations of verifying each
- B. Select options from file menu
  - 1. Select and answer appropriate questions:
    - a. NC program
    - b. Define measurement units
    - c. Set-up file
    - d. Translate NC code to RVP file if needed
    - e. Stock parameters
    - f. Define and describe upgrades available
    - g. Define tools
    - h. Choose preferred editor
    - i. Define machine controller
  - 2. Explain selected options
- C. Select options from options menu
  - 1. Select and answer appropriate questions:
    - a. Pause process options
    - b. Axis rotation of model
    - c. Step size options
    - d. Light source rotation onto model
    - e. Rapid threshold feed rate
    - f. .STL file import for surface comparison
    - g. Spindle check for rotation and direction
    - h. Calculation for milling cycle time
    - i. Volume of material removed during machining
  - 2. Explain selected options
- D. Describe model selection options
  - 1. Describe application, strengths and limitations of:
    - a. Preview

    - b. Verify
    - c. Turbo
- E. Select examine selection options
  - 1. Select and use examine selection options to include:
    - a. X-section "cross section"
    - b. Color tools option
    - c. CMM inspection
    - d. Zoom functions
    - e. Measurement
- F. Select window selection options
  - 1. Select and use window selection options to include:
    - a. Statistics on/off
    - b. Maximize window
    - c. NC file display on/off
    - d. Tile command
    - e. Control display on/off
- G. Use help menu options
  - 1. Locate and describe help menu options to include:
    - a. Contents of help menu
    - b. Memory information for applications
    - c. Search for help on topic
    - d. Version call out for software
    - e. Instructions on how to use help menu
- H. Use control menu options
  - 1. Describe and use:
    - a. Control go
    - b. Control restart
- I. Exit software
  - 1. Exit software application

CNC-H5-HO
Use the Internet
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this module the student will be able to:
- a. Access and use modem connection;
- b. Access and use the Internet;
- c. Discuss and apply different aspects of the Internet;
- d. Download files using the Internet;
- e. Access various user groups; and,
- f. Create basic web page using Netscape Navigator Gold.

Module Outline:

- I. Access and Use Modem Connection
    - A. Describe how modems communicate
    - B. Describe various standards and settings used in communication
    - C. Change modem and software settings as necessary
    - D. Describe various software for modem use
- II. Access and Use Internet
    - A. Describe the history of Internet
    - B. Describe theory and application of Internet
    - C. Describe basic HTML use
    - D. Discuss and apply different aspects of the Internet
        - 1. Web browsing (surfing)
        - 2. E-mail
        - 3. File transfer protocols
        - 4. Search engines
    - E. Describe and use various web browsers
        - 1. Netscape Navigator
        - 2. Microsoft Internet Explorer
    - F. Create basic web page using Netscape Navigator Gold
        - 1. Backgrounds
        - 2. Animated .GIF files
        - 3. Hyper Links
        - 4. Indexing Properties
            - a. Tables
            - b. Links
            - c. Targets
        - 5. Using .JPG Images
            - a. Inserting images
            - b. Resizing images

    - c. Linking images
    - d. Creating graphic images
    - e. Graphic programs to manipulate images
6. Registering web sites with search engines

CNC MACHINIST .... **programs, edits, sets up, and operates CNC lathes, mills and grinders to perform machining operations necessary to produce workpieces to referenced engineering standards.**

	Duties	← **Tasks** →												
A	Practice Safety	A-1 Follow safety manuals and all safety regulations/ requirements	A-2 Use protective equipment	A-3 Follow safe operating procedures for hand and machine tools	A-4 Maintain a clean and safe work environment	A-5 MSDS/ control chemical hazards								
B	Apply Mathematical Concepts	B-1 Perform basic arithmetic functions	B-2 Convert fractions/ decimals	B-3 Convert Metric/ English measurements	B-4 Perform basic algebraic operations	B-5 Use practical geometry	B-6 Understand basic trigonometry	B-7 Calculate speeds and feeds for machining	B-8 Use coordinate systems					
C	Interpret Engineering Drawings and Control Documents	C-1 Identify basic layout of drawings	C-2 Identify basic types of drawings	C-3 Review blueprint notes and dimensions	C-4 List the purpose of each type of drawing	C-5 Verify drawing elements	C-6 Practice Geometric Dimensioning and Tolerancing (GD&T)	C-7 Analyze bill of materials (BOM)	C-8 Describe the relationship of engineering drawings to planning	C-9 Understand and use quality systems	C-10 Verify standard requirements			
D	Recognize Different Manufacturing Materials and Processes	D-1 Identify materials with desired properties	D-2 Identify materials and processes to produce a part	D-3 Describe the heat treating process	D-4 Test metal samples for hardness	D-5 Understand welding operations								
E	Measure/ Inspect	E-1 Understand metrology terms	E-2 Select measurement tools	E-3 Measure with hand held instruments	E-4 Eliminate measurement variables	E-5 Measure/ inspect using surface plate and accessories	E-6 Inspect using stationary equipment							
F	Perform Conventional Machining	F-1 Prepare and plan for machining operations	F-2 Use hand tools	F-3 Operate power saws	F-4 Operate drill presses	F-5 Operate vertical milling machines	F-6 Operate horizontal milling machines	F-7 Operate metal cutting lathes	F-8 Operate grinding/ abrasive machines					
G	Perform Advanced Machining	G-1 Understand CNC basics	G-2 Program CNC machines	G-3 Operate CNC machining centers (mills)	G-4 Operate CNC turning centers (lathes)									
H	Use Verification and Communication Systems	H-1 Use personal computer	H-2 Use various operating systems	H-3 Use computer communications systems	H-4 Use verification systems	H-5 Use the Internet								
I	Program Using CAM System	I-1 Understand CAD/ CAM programs	I-2 Manipulate CAD functions	I-3 Process simple tool-path data	I-4 Create advanced surface models	I-5 Process complex tool-path functions								

CNC-I1-HO
Understand CAD/CAM Programs
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this module the student will be able to:

- a. Describe various CAD/CAM software;
- b. Describe differences between CAD/CAM;
- c. Discuss various software packages; and,
- d. Describe various requirements for CAD/CAM software.

Module Outline:

- I. Demonstrate Understanding of CAD/CAM Programs
  - A. Explain CAD/CAM programs
    - 1. Define Computer Aided Design (CAD)
    - 2. Define Computer Aided Manufacturing (CAM)
    - 3. Describe common applications of CAD and CAM
    - 4. Discuss common CAD packages to include:
      - a. AutoCAD
      - b. CadKey
      - c. Micro Station
    - 5. Discuss Common CAM packages to include:
      - a. MasterCam
      - b. SurfCam
      - c. SmartCam
    - 6. Describe common applications of CAD package design areas
      - a. Architectural
      - b. Electronics
      - c. Mechanical
  - B. Discuss various design modeling databases
    - 1. Wire Frame
    - 2. Surface Models
    - 3. Solid Models
- II. Describe Various Abilities of CAD/CAM
  - A. Discuss common applications of CAM software for:
    - 1. Vertical Machining applications
    - 2. Turning applications
    - 3. Grinding applications
    - 4. E.D.M. Applications
  - B. Discuss benefits of using:
    - 1. Wire Frame
    - 2. Surface Models

        3. Solid Models
    C. Discuss flexibility and increased production for application of:
        1. CAD for Design
        2. CAM for Manufacturing

III. Describe Various Requirements for CAD/CAM Software
    A. Computer hardware
    B. Computer operating systems
    C. Education/Training

CNC-I2-HO
Manipulate CAD Functions
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this module the student will be able to:

a. Demonstrate the correct use of CAD/CAM software to generate basic 2-dimensional shapes; and,

b. Demonstrate the correct use of CAD/CAM software to generate basic 3-dimensional shapes.

Module Outline:

I. Access CAD Program Options
  A. Explain the configuration of CAD/CAM software
    1. Explain configuration of:
      a File and path names
      b. Installation, including DOS and Windows
      c. Configure software
      d. Interaction of files between each other
    2. Describe the "flow" process of CAD/CAM
  B. Access CAD software
    1. Access CAD software, including AutoCAD and CadKey, to:
      a. Create basic 2-dimensional designs
      b. Create 3-dimension designs
      c. Dimension designs to be used as drawings
      d. Create title blocks and borders for prints
      e. Print drawings
      f. Plot drawings
      g. Create general and local drawing notes and tolerances
    2. Describe various file conversion formats
    3. Import and export designs using conversions, including:
      a. IGES
      b. CADL
      c. DXF
      d. STL
  C. Access CAM software
    1. Load existing design
    2. Import and export design files from various file format standards, including:
      a. IGES
      b. DXF
      c. CADL

      d. STL
    3. Save design files to “permanent” memory
    4. Access CAD section of CAM software to create
      a. Create basic 2-dimensional designs
      b. Create 3-dimension designs
      c. Dimension designs to be used as drawings
      d. Create title blocks and borders for prints
      e. Print drawings
      f. Plot drawings
      g. Create general and local drawing notes and tolerances

II. Create Basic Geometric Entities
  A. Create basic geometric entities, including:
    1. Points
    2. Fillets
    3. Lines
    4. Splines
    5. Arcs
    6. Chamfers
    7. Circles
    8. Letters including various machinable fonts
  B. Dimension completed designs to create detailed drawings
  C. Transform geometric entities using CAD commands
    1. Transform geometric entities, including:
      a. Mirror entities
      b. Rotate entities
      c. Scale complete entities using single scale option
      d. Translate using move and copy options
      e. Offset single and grouped geometric entities
      f. Use group function to effect multiple entities simultaneously
      g. Use result function to effect group movements
  D. Set menu selections to:
    1. View planes
    2. Construction planes
    3. Color choices
  E. Use Delete command:
    1. Use Delete commands, including:
      a. Chained and duplicate entities
      b. Exclusive entities (only)
      c. Inclusive entities (all)
      d. Enclosed in window
      e. Intersecting window
  F. Execute screen and display functions
    1. Use screen and display functions to:
      a. List screen statistics

    - b. Display entity endpoints
    - c. Clear group and result color designation
    - d. Change colors of entities
    - e. Display window
    - f. Un-zoom display
    - g. Change levels of entities
    - h. Fit entities to screen
    - i. Set various view ports
    - j. Refresh screen
    - k. Change views
    - l. Set active levels
    - m. Change entities between levels
    - m. Set screen center "pan"
    - n. Initialize display "clear"
    - o. Rotate display

G. Use analyze function
  1. Use analyze function to interpret:
    - a. Point descriptions
    - b. Single entity information
    - c. Locations of entities
    - d. Distance between points
    - e. Area calculations
    - f. Calculation of angles

CNC-I3-HO
Process Simple Toolpath Data
Attachment 1: MASTER Handout

Objective(s):

Upon completion of this module the student will be able to:

- a. Properly identify various parts of CNC program generation;
- b. Demonstrate the use of the post-processor and co-processor for intermediate CNC data;
- c. Perform editing of CNC programs using various software; and
- d. Perform verification of completed toolpaths.

Module Outline:

- I. Generate Numerical (NC) Code
  - A. Generate NC code to access:
    - 1. Turning center "lathe"
    - 2. Vertical machining center "mill"
- II. Generate Basic Vertical Machining Code
  - A. Generate basic vertical machining code for operations, including:
    - 1. Outside and inside contours
    - 2. Pocketing operations
      - a. Islands
      - b. Multiple "Z" level islands
    - 3. Drilling, reaming, spot drilling, tapping operations
- III. Program Lathe or Turning Operations
  - A. Use CAD section to create geometric designs
  - B. Create lathe tools as required
  - C. Create toolpath information to rough and finish
    - 1. Create toolpath information to rough and finish during:
      - a. Turning operations
      - b. Facing operations
      - c. Grooving operations
      - d. Internal boring operations / external boring operations
      - e. Internal and external threading
  - D. Edit toolpath data files
    - 1. View and edit tool path data files, including:
      - a. Display centerline tool path
      - b. Calculate time to machine
      - c. Filter tool path data to reduce size and time
      - d. Change feed rates and compare results
      - e. Edit tool path data to change possible variables
      - f. Define tool selections and operating parameters

        - g. Define materials to be machined
        - h. Create set-up document
    - 2. Verify toolpaths by cutting part as solid model
    - 3. Verify toolpaths by "backplotting" toolpaths
- E. Process Tool Path Data to Numerical Control Code
    - 1. Select post processing file relative to machine tool being used
    - 2. Execute post processing function
    - 3. Edit numerical control program if needed
- F. Describe and Execute Post-Processor or Co-processor Functions
    - 1. Describe post-processor and co-processor functions
    - 2. Run processors

CNC-I4-HO
Create Advanced Surface Models
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this module the student will be able to demonstrate the correct use of CAD/CAM software to create 2- and 3-dimensional geometric shapes and surface models.

Module Outline:

I. Create Advanced Designs with CAD Section of CAD/CAM Program
  A. Create advanced geometric surfaces
    1. Create advanced geometric surfaces to include:
      a. Lofted / *Cross Section*
      b. Blend
      c. Swept / *Drive Curve*
      d. Trim
      e. Coons / *4-Curve*
      f. Draft
      g. Offset
      h. Nurb Surface
      i. Fillet
      j. Parametric Surface
  B. Edit geometric entities
    1. Modify and edit advanced geometric surfaces to include:
      a. Trimming
      b. Breaking
      c. Joining
      d. Fillet
  C. Edit advanced geometric surfaces
    1. Modify and edit advanced geometric surfaces to include:
      a. Control points of nurbs
      b. Conversion to nurbs entity
      c. Extend entities
      d. Drag entities
      e. Edit entities
    2. Change cutter offset side
    3. Change cutting directions
    4. Turn surface normal arrows on and off
    5. Decompose composite surfaces
    6. Twist vectors of parametric surface
    7. Create polygons on surface

        8. Align surface normals
        9. Trim surfaces
        10. Untrim trimmed surfaces
    D. Transform geometric entities using CAD commands
        1. Scale X, Y, and Z at possible separate ratios
    E. Execute screen and display functions
        1. Use screen and display functions to:
            a. Change surface density
            b. Shade surface models
            c. Blank and unblank entities

CNC-I5-HO
Process Complex Toolpath Functions
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this module the student will be able to:

1. Demonstrate an understanding of the use of single surface machining;
2. Demonstrate an understanding of the use of multiple surface machining;
3. Demonstrate an understanding of the use of multiple tool planes and multi-axis machining; and,
4. Digitize existing objects to create new toolpaths.

Module Outline:

I. Process Tool Path Data
  A. Generate advanced vertical machining code
    1. Generate code for three axis surface machining to include:
      a. Single surface machining,
        1) Create roughing toolpaths
        2) Create finishing toolpaths
      b. Multiple surface machining
        1) Create roughing toolpaths
        2) Create finishing toolpaths
    2. Generate code for four and five-axis surface machining to include:
      a. Single surface machining
        1) Create roughing toolpaths
        2) Create finishing toolpaths
      b. Multiple surface machining
        1) Create roughing toolpaths
        2) Create finishing toolpaths
  B. Import and machine scanned data
    1. Import and machine three-dimensional data
      a. Collect data points using C.M.M.
      b. Collect data using vertical machining center and digitizing probe
      c. Convert scanned data into usable geometric entities
      d. Create appropriate surface types from wireframes
      e. Generate numerical control programs using surface models
  C. Verify toolpaths
    1. Verify multi-surface toolpaths

  2. Verify 4th and 5th axis machine code

D. Describe and execute post-processor or co-processor functions

  1. Edit processors for 4th and 5th axis machining
  2. Process intermediate files into NC code